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EFFECTS OF GASOLINE ADDITIVES ON CARBURETOR AND PCV SYSTEM PERFORMANCE AS THEY RELATE TO EXHAUST EMISSIONS

First Year Report

Prepared for

COORDINATING RESEARCH COUNCIL, INC.

NATIONAL AIR POLLUTION CONTROL ADMINISTRATION

DEPARTMENT OF HEALTH, EDUCATION AND WELFARE

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APRAC Project Number CAPE 2-68
Scott Project #2807

Prepared For

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TABLE OF CONTENTS

		Page No.
1.	INTRODUCTION	1-1
2.	FIRST YEAR PROGRAM	2-1
	2.1 Car Preparation	2-1
	2.2 Exhaust Emission Tests	2-3
	2.3 Test Operations	2-7
3.	SIGNIFICANT PROBLEMS	3-1
	3.1 Ignition Knock Survey	3-1
	3.2 Carburetor Deposits, Car Number 18	3-2
4.	RESULTS AND DISCUSSION	4-1
	4.1 Exhaust Emission Data	4-1
	4.2 Fuel Composition Differences	4-13
	4.3 Conclusions	4-16
5.	APPENDIX TO SECTIONS 2 AND 3	
	5.1 Initial Shop Procedures, Fuel Additives Program	5-1
	5.2 Pre Emission Test Tuneup Summary	5-6
	5.3 Carburetor Specification Sheet	5-8
	5.4 Bench Flow Characteristics	5-9
	5.5 Test Fleet Identification	5-10
	5.6 Test Fuel Analyses	5-13
	5.7 Fuel and Mileage Record	5-14
	5.8 Ignition Knock Survey Results	5-15
6.	APPENDIX TO SECTION 4	
	6.1 Test Data at 0 Test Mile	6-1
	6.2 Test Data at 4,000 Test Mile	6-4
	6.3 New Multiple Range Test	6-7
	6.4 Analysis of Variance	6-10
	6.5 Mean Values of Significant Interactions	6-29

Scott Research Labs., Inc.
Project #2807

April 30, 1970

ABSTRACT

The purpose of this project is to study the effects of gasoline additives on carburetor and PCV system performance as they relate to exhaust emissions. Three groups of 16 cars each or a total of 48 fleet vehicles are being driven in normal urban and suburban modes of operation over a 24,000 mile interval under controlled fuel conditions and maintenance. Each group of 16 cars is being operated on the same base fuel. Two of the three group's test fuels contain a gasoline additive (supplied by CRC) which is added to the base fuel.

During the First Year Program, exhaust emission measurements were made as the vehicles started the test and at each subsequent 4,000 mile interval. An analysis of variance was conducted on each of 19 emission parameters for the zero and 4,000 mile interval. A major conclusion reached on the basis of these analyses is that: no significant differences in emission parameters were determined at the 4,000 mile point on the basis of fuel employed. A secondary conclusion drawn concerns the make factor. That conclusion is: all emissions parameters vary significantly between makes; however, no single make is consistently the highest or lowest valued across the spectrum of the 19 emissions parameters measured. The VW vehicles were distinctly different to such a degree that their data were not included in the final analysis.

The test fleet is continuing to accumulate mileage into the second year. The second year program began April 1, 1970.

1. INTRODUCTION

Carburetor throttle body deposits normally form during idle periods when the throttle plate is nearly closed. Because of the small space between the throttle plate and the throttle body, air entering the engine passes this point at a very high velocity. Any contaminants contained in the intake air tend to be centrifuged out and deposited on the throttle body. In addition, blowby gases flowing into the intake air stream under certain conditions (as may be caused by a plugged PCV valve), tend to accentuate the deposit problem. Crankcase blowby is also conducive to deposit formation in the PCV valve.

Considerable work has been done on the effect of lubricating oil, oil drain periods, and fuel additives on PCV valve and carburetor cleanliness; however, very little information was available on the effects of fuel additives as they relate to exhaust emissions. In order to determine the magnitude of these effects, controlled field test under realistic conditions by measuring exhaust emissions and PCV valve flow at regular test mileage intervals was necessary.

The Gasoline Additive Study is designed to measure the effects of gasoline additives on carburetor and PCV system performance as they relate to exhaust emissions. The program is designed to yield data from which maximum information on the gasoline additive effects can be developed. Three groups of 16 cars each or a total of 48 fleet vehicles are planned to be driven in normal urban and suburban modes of operation over 24,000 miles under controlled fuel conditions and maintenance.

2. FIRST YEAR PROGRAM

This section covers the procedures for car preparation, test operations and the exhaust emission tests for the program.

2.1 CAR PREPARATION

Pre-Test Mileage Accumulation: At the beginning of the first year test program, 18 new vehicles were leased by Scott. This fleet was supplemented by the County of San Bernardino which added 30 new vehicles. Each vehicle was required to accumulate 3,000 miles before it was to be modified for the Gasoline Additives Program. This period was required to stabilize engine deposits. Both groups of vehicles were operated on commercial premium fuels during the pre-test mileage accumulation period.

Initial Tuneup: After the initial 3,000 miles had been accumulated, each car received a major tuneup as outlined in the Pre-Emissions Tuneup and Maintenance procedures shown in the Appendix Section 5.1. The cars received a detailed electrical tuneup and parameters were adjusted to manufacturer's specifications. A tuneup specification summary sheet for all fleet cars is shown in Table 2.1. The electrical tuneup consisted of installing new plugs, points, condenser, and checking the mechanical and vacuum advance systems. The tuneup data were recorded on the Pre-Emission Test Tuneup Summary (Appendix 5.2). The tuneup included the installation of a new "flowed" carburetor which was procured from each manufacturer. All carburetor adjustments were checked for correct internal and external

2.1 CAR PREPARATION - continued

mechanical adjustments prior to installation. Carburetor mechanical adjustments were made in accordance to manufacturer's specifications, and the data recorded as shown in Appendix 5.3. Idle mixture adjustments were made during the exhaust tests (see Section 2.2).

The initial tuneup also included a new PCV valve which was flow tested and installed. Typical flow curves are presented in Appendix 5.4. Flow in SCFM through the valve was corrected to 29.92" Hg and 70°F. Flow data were measured at each 1" Hg Δ P (from 1-18" Hg ΔP).

Fuel Tank Modification: In order to assure accurate control for the dispensing of the three test fuels, a unique system of gas pump nozzle and gas tank fill pipe mating was devised. The design employed the use of a metal "freeze plug" mounted just inside the fill pipe. A hole of such geometric design was cut out of the freeze plug so that only a nozzle with the same design can be inserted to dispense gasoline into that vehicle. A locking gas cap was color coded to the gas pump containing the assigned fuel for that vehicle. The geometric freeze plug shapes are shown in Appendix 5.1 (page 5-2). At the time of fuel tank modification the tank fuel was removed and refilled with the assigned test fuel.

2.2 EXHAUST EMISSION TESTS

Idle Mixture Adjustment: Prior to the initial exhaust emissions tests, the idle mixture and speed were adjusted in accordance with the manufacturer's specifications (Table 2.1). Idle speed and mixture screws were locked to prevent further adjustment during mileage accumulation (see Appendix 5.1).

Table 2.1 1969 Tuneup Specification Summary

Car Make/ No.	Engine CID	Air Cond	Ignition Specifications: Spark Plug Gap, Inches	Point Dwell, °	Basic Timing	Total Advance, ° (@ RPM)	Mech. Advance, ° (@ RPM)	Idle Specifications: RPM	CO	AFR	Ref
Chev/1	327	No	0.035	28 32	2° BTC	27 (2000)	12 (2000)	600 D	None	None	1
Chev/1	327	Yes*	0.035	28 32	2° BTC	27 (2000)	12 (2000)	600 D	None	None	2
Chev/2	250	Yes*	0.035	31 34	4° BTC	40 (1950)	17 (1950)	550 D	None	None	3
Ford/3	390	Yes*	0.032 0.036	26 31	6° BTC	28.5 38 (2000)	10.5 15 (2000)	550 D		14.4	4
Ford/4	302	No	0.032 0.036	26 31	6° BTC	30 39.5 (2000)	12 16.5 (2000)	550 D		13.8	5
Plym/5	318	Yes*	0.035	30 35	TDC	31.5 40.5 (1700)	15 19 (1700)	650 N		14.2	6
VW/6	91	No	0.026	47 53	TDC	32** 35 (2000)	None	850 N	None	None	7

REFERENCES FOR IDLE MIXTURE ADJUSTMENT PROCEDURES

1. Page 6M1, 1969 Chevrolet Chassis Service Manual.
2. Page 6M1, 1969 Chevrolet Chassis Service Manual.
3. Page 6M1, 1969 Chevrolet Chassis Service Manual.
4. Pages 10-01-05 through 07, Volume 2, Engine; 1969 Ford Shop Manual.
5. Pages 10-01-05 through 07, Volume 2, Engine; 1969 Ford Shop Manual.
6. Pages 14-2 and 3, 1969 Plymouth Service Manual.
7. Section 3, Adjusting Engines with Exhaust Control System, VW Shop Manual.

* Air Cond off for all adjustments
** All vacuum advance (combined engine load and speed control in carburetor), no mechanical advance.

2.2 EXHAUST EMISSION TESTS - continued

Exhaust Emission Measurements: Exhaust emission tests were conducted in triplicate at the 0 mile test interval. The vehicles were preconditioned by cruising at 40 MPH for 15 minutes followed by driving four 7-mode cycles. Exhaust emissions from the last two 7-mode cycles were sampled and measured in accordance with the 1968 and 1969 Federal procedures (Federal Register, Volume 31, Number 61, March 30, 1966), with the exception that the vehicles assigned test fuel was used instead of the fuel prescribed in the Federal Register.

At the end of the 7-mode cycle sampling, emissions were measured during steady state modes of 20 MPH, 40 MPH, and idle (in this order). The vehicles were stabilized at 20 MPH (top gear) for three minutes. Average exhaust emissions (ppm hydrocarbon by NDIR and FID, volume percent CO, CO_2, and O_2) were recorded for a 15 second period commencing at the end of the stabilization period. This procedure was repeated at 40 MPH, and at idle (stabilizing period at idle was one minute). The vehicle's assigned test fuel was used for all exhaust tests.

Emission Testing Schedule: Exhaust emission measurements of each vehicle were conducted in triplicate at the start of the program and single tests were conducted at the 4,000 mile test interval and are planned at every subsequent 4,000 mile interval out to 24,000 miles (except when engine malfunctions required special maintenance as described below). Prior to emission sampling, the ignition system of the vehicle was checked with an Autoscan ignition analyzer. Faulty points, plugs, condensers, wiring, air

Each group of 16 cars is being operated on the same base fuel. Two of the three group's test fuels contain a gasoline additive (supplied by CRC) which is added to the base fuel.

Exhaust emission measurements were conducted at the beginning of the program and at the 4,000 test mile interval. A remeasurement of these emissions is planned at each 4,000 mile interval through the program. Statistical analysis of variance (AOV) was applied to the data at the start and the 4,000 test mile interval to analyze fuel, mile interval, make, and their respective interactions as they relate to exhaust emissions.

As the fleet continues to accumulate mileage, engine tuneup maintenance is being conducted as specified by the manufacturer except for the PCV valves and carburetor idle adjustments.

This first year final report includes all of the test work conducted during the first year of test operations. Currently, all vehicles have completed the 0 and 4,000 mile tests. A discussion of the exhaust emission results and the analysis of variance for the 0 and 4,000 mile interval is presented.

The test fleet is continuing to accumulate mileage into the second year.

2.2 EXHAUST EMISSION TESTS - continued

filters, and fuel filters were changed or adjusted as necessary to manufacturer's specifications. Timing was reset to manufacturer's specifications prior to the exhaust tests (see Section 3.1). Idle speed and mixture were not adjusted. PCV valves received no maintenance.

At the 12,000 test mile interval, each vehicle will receive an ignition tuneup as specified by the manufacturer. Exception to the above is when a vehicle exhibits continued stalling between test intervals; i.e., the engine will not idle. The stalling in such a vehicle will be diagnosed at the time of the complaint by a Scott technician. The vehicle will be returned to the fleet if maintenance of the ignition system eliminates the stalling.

If idle quality is not restored because of ignition problems and no other explanation for the stalling can be found (except attributable to the PCV system or carburetor), the following procedure will be executed. The exhaust emissions will be measured and a new PCV valve will be installed. If stalling is eliminated, the emissions will be remeasured and the vehicle will be returned to the fleet. If stalling continues after the new PCV valve is installed, the original PCV valve will be reinstalled, and the carburetor will be adjusted or cleaned if necessary to restore idle quality. The emissions will be remeasured and the vehicle will then be returned to the fleet for continuing mileage accumulation.

At the end of the mileage accumulation period (24,000 miles), the exhaust of each vehicle will be measured as described above. Following

2.2 EXHAUST EMISSION TESTS - continued

this the carburetor will be photographed and cleaned, the exhaust emissions remeasured, a new PCV valve will be installed, and exhaust emissions measured in duplicate for the final time.

Calculation Procedures: Federal 7-mode cycle and the steady state emissions are time integrated, corrected, and weighted in accordance with the Federal procedures outlined in the Federal Register, Volume 31, Number 61, March 30, 1966. These procedures apply to 1969 vehicles which is the year model cars being used in this test. After the curves are time integrated, the weighted emissions are calculated on an IBM S360 computer. In addition, the 7-mode cycle mass emissions are calculated from the concentration calculations in accordance with the 1970 Federal procedures outlined in the Federal Register, Volume 33, Number 108, June 4, 1968.

Manual Versus Computer Calculations: In order to compare the accuracy of the computer calculations, 7-mode exhaust emissions for three vehicles were hand calculated. This comparison includes only the arithmetic calculations. The results are as follows:

	Car No.	Manual Calculation	Computer Calculation	Difference Percent*
HC, ppm	6	212.20	212.17	0.01
	24	251.61	212.71	0.03
	47	296.05	295.74	0.03
CO, %	6	0.386	0.386	0.00
	24	0.936	0.937	0.10
	47	0.817	0.804	1.59

* Difference, % = (Difference/Manual Calculation)(100)

2.3 TEST OPERATIONS

Test Fleet: The test vehicles were selected from the most cost effective sources in which maximum fleet control could be maintained. Thirty 1969 San Bernardino Count vehicles and eighteen 1969 Scott leased vehicles make up the test fleet as follows:

No. of Cars	Make	Model	Engine Size, CID
9	Chevrolet	Chevelle	250
9	Chevrolet	Biscayne	327
9	Ford	Custom	302
9	Ford	Galaxie	390
9	Plymouth	Fury I	318
3	Volkswagon	1131	78
48			

Before any fleet preparation took place, all 48 fleet vehicles were divided into three fuel groups of 16 each with equal numbers by make and engine displacement in each group. A more complete test fleet identification is listed in Appendix 5.5.

Test Fuels: As discussed above, the fleet was divided into three fuel groups as follows:

Car Number	Test Fuel Number	Test Fuel Color Code	Additive Identification
1-16	1	Red	None
17-32	2	White	White
33-48	3	Blue	Blue

2.3 TEST OPERATIONS - continued

The gasoline additive was supplied by CRC and blended into the base test fuel (Red) at the concentration of one (1) gallon per 1,000 gallons of gasoline which yielded the white and blue test fuels.

The base test fuel (red) was designated as MS08 which is purchased from American Oil for mileage accumulation and testing. Appendix 5.6 lists the analyses of the MS08 test fuel for the three batches received to date.

Fleet Control: An important phase in the program is the absolute control of the operation of the vehicles; primarily, the absolute control of dispensing the fuel to each test vehicle, its maintenance and records, and the proper mileage accumulation rates. A written agreement between San Bernardino County and Scott specified conditions for maintaining fleet control and the integrity of the Fuel Additives Program.

Briefing Participants: Scott was assured of maximum cooperation by San Bernardino County fleet managers who were thoroughly briefed about the purposes of the program and the necessary controls to produce valid test results. Each driver of the test vehicle was given a description of the test progran and each vehicle had decals appropriately placed on the dashboard in full view of the driver, and another decal under the hood of the vehicle reminding the operator of the need to notify Scott of any mechanical problems. In addition, detailed instruction booklets were put in the glove compartment of each vehicle.

2.3 TEST OPERATIONS - continued

Mileage Accumulation: The mileage accumulation of the fleet vehicles ranges from 1,000 to 2,000 miles per month. This mileage is accumulated in city-suburban type driving and includes some freeway driving. All vehicles are operated on routes with a one source fuel supply (Scott), and do not exceed a range of approximately 200 miles before refueling.

A summary of the total fleet mileage accumulation is shown in the following table:

No. of Cars	Fuel Color	Total Mileage*	Average January Mileage	Number of Cars* Test 1,2,3 (0 Miles)	Test 4 (4,000 Miles)	Test 8 (8,000 Miles)	Test 12 (12,000 Miles)
16	Red	164,937	1,309	16	16	14	3
16	White	177,409	1,303	16	16	15	5
16	Blue	144,895	1,223	16	16	11	0
48		487,241	1,278	48	48	40	8

* First year mileage to March 1, 1970.

The 48 car average mileage is plotted in Figure 2.1. Each vehicle's mileage accumulation rate was plotted from their respective start dates. The accumulated test miles were read from each chart at one month time intervals and then averaged. The first vehicle was modified and began accumulating mileage on June 2, 1969. The last of the 48 car fleet was modified on August 13, 1969. Figure 2.1 shows that fleet as a whole is averaging approximately 1,280 miles per month at the 7 month interval.

Fuel Control and Consumption: Absolute fuel control is achieved through the use of single source fuel supply at Scott under the direct control

Scott Research Labs., Inc.
Project #2807

2-10

April 30, 1970

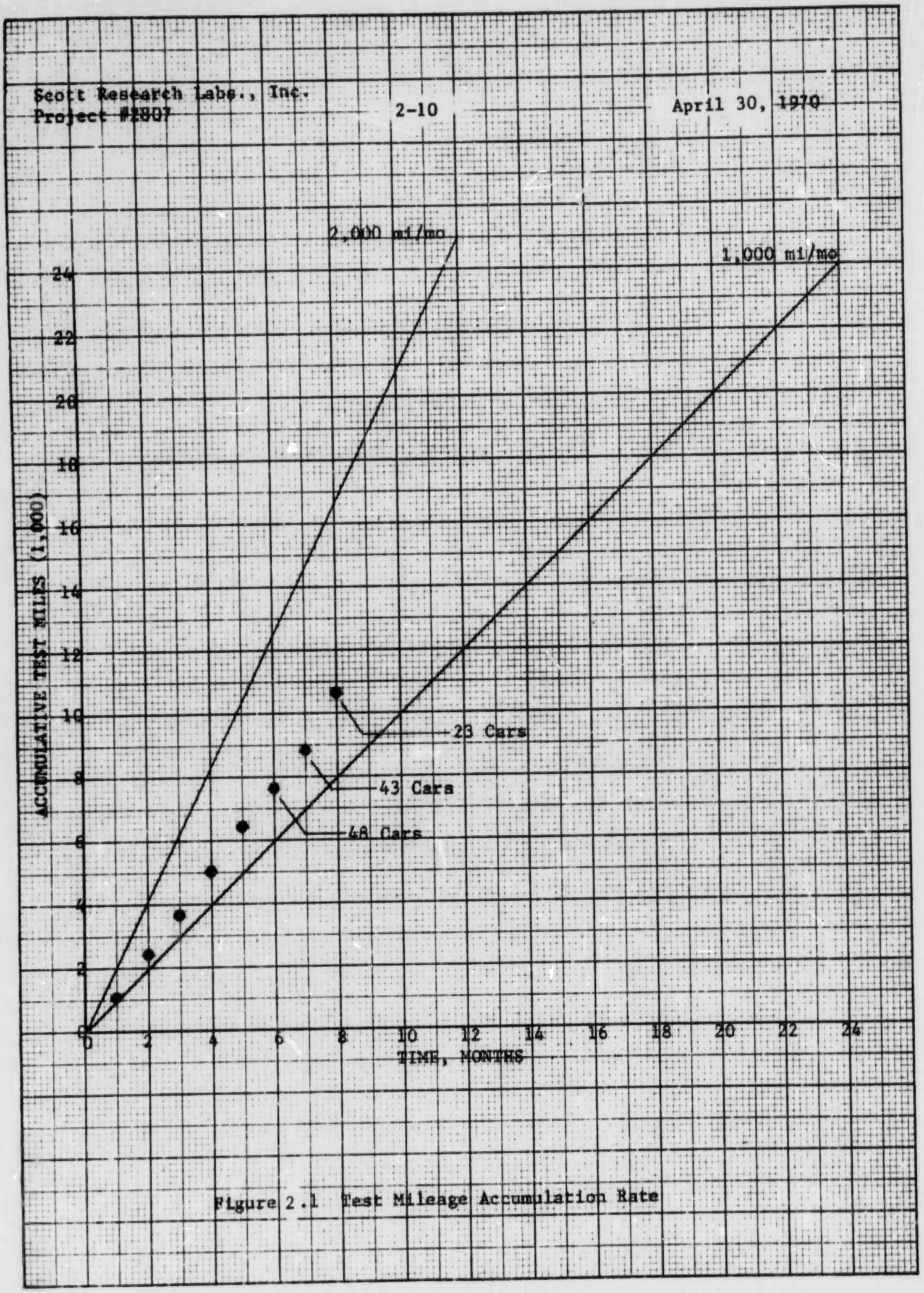

Figure 2.1 Test Mileage Accumulation Rate

2.3 TEST OPERATIONS - continued

of a Scott technician. His job is to control dispensing of fuel and recording the pertinent data at each fuel fill such as odometer mileage and total gallons. The vehicles are fitted with locked gas caps as well as the matched geometrically shaped gas pump nozzle and gas tank fill pipe described in Section 2.1. Scott has possession of the locked gas cap keys.

Fuel consumption is calculated on a per tank basis and a cumulative average is tabulated. A sample fuel and mileage record is shown in Appendix 5.7.

Maintenance and Oil Change: All vehicles were thoroughly checked at the start of the program as described in Appendix 5.1. As the vehicles accumulated mileage, they were inspected and tuned, if necessary, prior to the emission test at 4,000 miles as described in Section 2.2. Scott performed all engine maintenance and oil changes specified by the manufacturer. All maintenance was performed according to the manufacturer's recommendations, with the exception of the PCV valve and carburetor idle adjustments.

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3. SIGNIFICANT PROBLEMS

3.1 IGNITION KNOCK SURVEY

Problem: Several compliants were received from the fleet drivers of all vehicle makes concerning ignition knock during cruise and light acceleration modes. As a result, Scott conducted an ignition knock survey on all 48 fleet vehicles which determined the severity of the knock problem. A Scott technician conducted a five minute road test on each vehicle as it came in for fuel. With the vehicle warmed up, the road test consisted of a high gear 20-60 MPH moderate acceleration (throttle at detent) and a 40 MPH cruise condition. Ratings were assigned as no knock, borderline knock, and above borderline.

Ignition Knock Survey Results: The ignition knock survey was conducted in September and October, 1969. The resulting data are presented in Appendix 5.8, and show that 46% of the vehicles had ignition knock, during the 20-60 MPH acceleration. Basic timing for twelve of the fleet vehicles exceeded 3^{o} retard from specifications. Five of the fleet vehicles rated above borderline knock were within a $\pm 3^{o}$ tolerance band.

Appendix 5.8 includes point dwell measurements. These data were used to determine if abnormal wear or maladjustment had effected the basic timing settings. The data show that four fleet vehicles had less point dwell (wider gap) than the specified range which would reflect a basic timing advance.

3.1 IGNITION KNOCK SURVEY - continued

Corrective Action: To preclude ignition knock, the CAPE 2-68 Committee outlined corrective policy. The basic timing of those vehicles with a knock problem was retarded. As the vehicles came in for exhaust tests, the basic timing was set to manufacturer's specification before the test. After the tests, the basic timing was reset to the retarded value. The retard valves used are:

Make-Engine CID	Basic Timing, Degrees Mfg. Specs.	Reset To:
Chevrolet-250	+4	+4*
Chevrolet-327	+2	-1
Ford-302	+6	+1
Ford-390	+6	+1
Plymouth-318	0	-3
Volkswagon-78	0	0*

* No change

Currently, fleet drivers are not complaining about ignition knock.

3.2 CARBURETOR DEPOSITS, CAR NUMBER 18

Carburetor Deposit Problem: At 6,500 test miles the driveability of car number 18 became very poor. The car would continually stall at idle and ran quite rough at low speeds. The exhaust gas appeared very rich and the car was smoking excessively during the idle mode. Prior to the 6,500 mile test point, the driver reported that the car's idle quality had been gradually deteriorating. However, the car performed satisfactorily during all other modes of operation.

3.2 CARBURETOR DEPOSITS, CAR NUMBER 18 - continued

A complete inspection was conducted which included the ignition and the PCV systems. Both systems were operating normally and the tune up parameter adjustments compared favorably with the measurements made at the 0 and 4,000 mile test interval. A new PCV valve was installed which produced no idle quality change.

Exhaust emission tests were conducted at the 6,500 mile test point which showed that the carburetor idle circuit was extremely rich (12% CO) and that the accel mode emissions were normal. Cruise modes were also rich (but less than idle) because of the influence of the idle circuit at 15 and 30 MPH.

Corrective Action: At the 6,500 mile test point corrective action was taken in accordance with instructions of the CAPE 2-68 Committee. It was decided to lower the idle CO to 6.00% and 600 RPM. The idle was readjusted to 600 RPM in drive and the mixture screws were turned into their seats (leaning) which resulted in a 9.9% CO (uncorrected). This was still high but the car idled satisfactorily and was not smoking. The Committee requested that the car be returned to normal service for continued mileage accumulation.

At the 8,000 mile test point, car 18 again was idling extremely rich and smoking excessively. The ignition and PCV systems were operating normally. The 8,000 mile exhaust emission test was conducted and again idle CO was extremely high (11%, uncorrected) at 350 in drive.

3.2 CARBURETOR DEPOSITS, CAR NUMBER 18 - continued

Corrective action at the 8,000 mile test point was again taken in accordance with the Committee's instructions:

1. Air cleaner (element tested "good" on an AC tester)
2. PCV line and fittings were open
3. Oil consumption (1940 miles/quart)
4. Clean carburetor (2 steps)
   - o Clean venturi main jet and idle cluster (only) and measure emissions
   - o Clean remainder of carburetor, adjust idle, and measure emissions

Inspection of the venturi cluster yielded no visible deposits in the idle passages. The outer cluster surfaces, however, were dark in color. The cluster was cleaned and reinstalled. The idle speed increased from 350 to 750 in drive and then was readjusted down to 600 in drive. The measured idle CO decreased from the high of 11% down to 0.1% without adjusting the mixture screws which were still seated as described above for the 6,500 mile tests.

The carburetor was then completely cleaned and reinstalled. Idle CO was readjusted to 1.0% (uncorrected) at 600 RPM in drive. Exhaust emissions were measured and the vehicle was returned to the fleet for continued mileage accumulation.

Table 3.1 and Figure 3.1 show a summary for all exhaust emissions tests through the 8,000 mile test point for this vehicle.

Table 3.1 Exhaust Emission Summary
Fuel Additives Test Fleet,
Car Number 18

Test Miles	Test No.	Test Condition	Measured Idle Quality RPM	Measured Idle Quality CO, %	Composite Hot Start 7-Mode Emissions HC, ppm	Composite Hot Start 7-Mode Emissions CO, %
0	1,2,3	After T.U.	600	0.9	248	0.50
4,000	4	As Received	350	5.8	496	2.75
6,500	42	As Received	300*	12.0*	1017	1.92
6,500	43	After Adjust	600	9.9	518	1.89
8,000	8	As Received	350	11.0	1703	3.71
8,000	81	After Venturi Cluster Cleaned	600	0.1	362	0.26
8,000	82	After Complete Carb. Clean and Idle Adjust	600	1.0	210	1.17

* Stalled continually (idle CO measured with foot on throttle at approximately 300 RPM)

Average Fuel Consumption = 11.0 mpg
Average Oil Consumption = 1940 miles/quart

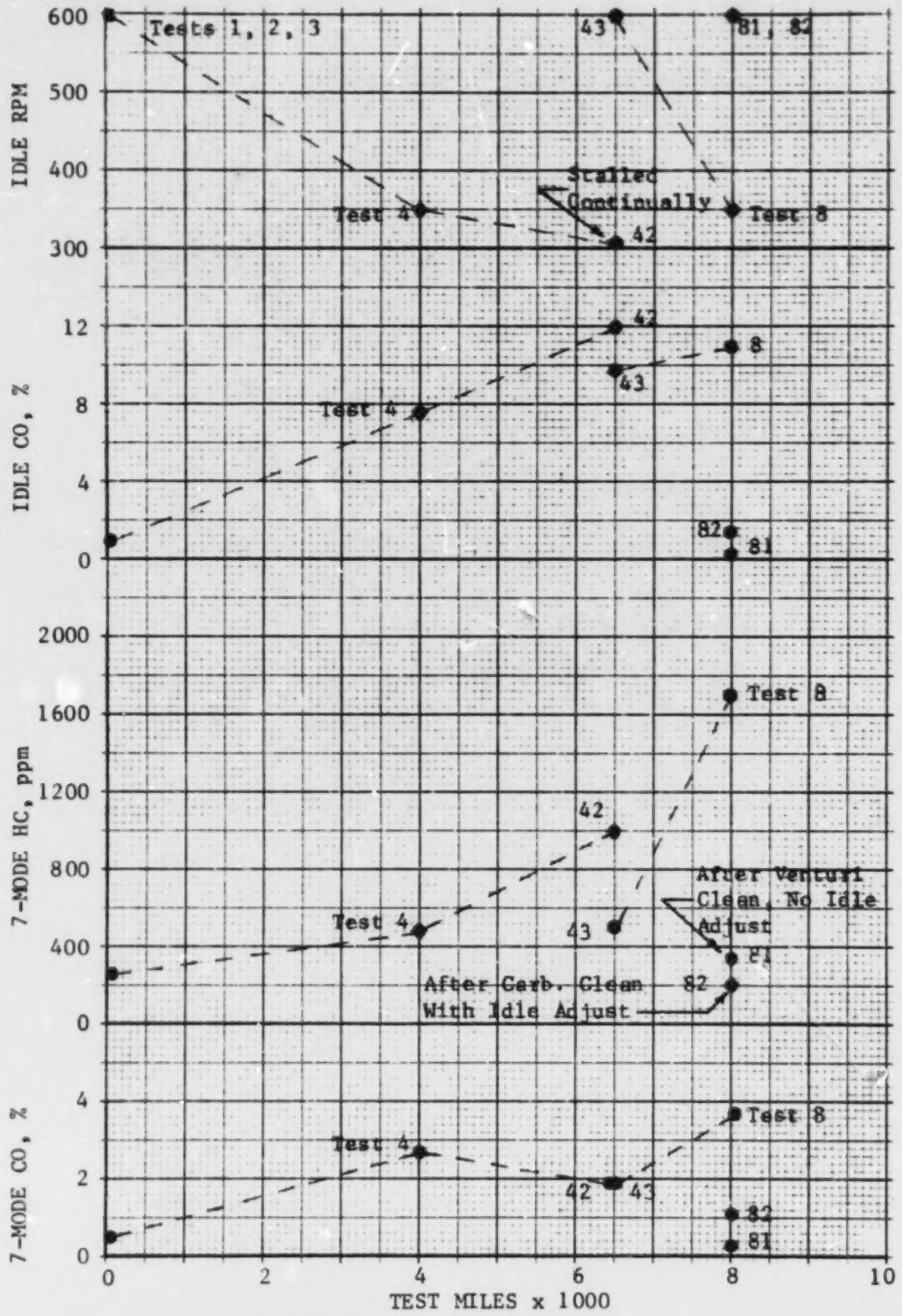

Figure 3.1 Exhaust Emissions Versus Test Mileage
Fuel Additives Test Fleet, Car No. 18

4. RESULTS AND DISCUSSION

4.1 EXHAUST EMISSION DATA

Both the zero mile and the 4,000 mile tests were completed in the first year. The data from these tests are presented in Appendix 6.1 and 6.2.

The general format of the data is illustrated by Table 4.1 which shows 7-mode carbon monoxide concentration values in volume percent, 7-mode hydrocarbon concentration values in parts per million on a volume basis, idle RPM, and PCV flow rates in standard cubic feet per minute.

A striking feature of these data is the degree to which the Make #6 (Volkswagen) data stand apart from those of the other makes. On the basis of this feature of the data, the Volkswagen is herein defined as distinctly different. Therefore, its data have been deleted from the comparison of mathematical variance within groups to the mathematical variance between groups (analysis of variance or AOV).

The tables of Appendix 6.2 show that data for some of the steady state parameters were not recorded for three to five of the vehicles at the 4,000 mile test interval. To preclude disproportionality in the cells of the AOV matrices, the average value for the steady state parameter of the other cars of the same make utilizing the same fuel at the same test interval were used to fill the voids.

Table 4.1

Car No.	Make	Fuel	7-Mode CO Values in % Test 1	7-Mode CO Values in % Test 2	7-Mode HC Values in ppm Test 1	7-Mode HC Values in ppm Test 2	Idle RPM Test 1	Idle RPM Test 2	PCV Flow (cu. ft./min.) Test 1	PCV Flow (cu. ft./min.) Test 2
1	1	1	0.75	1.57	210.80	244.54	600	620	1.70	1.82
2	1	1	0.46	1.90	233.08	276.38	600	580	1.61	1.85
3	1	1	0.56	0.90	241.62	189.94	600	620	1.75	1.80
17	1	2	0.50	0.94	260.10	219.07	600	630	1.70	1.85
18	1	2	0.48	2.78	233.55	496.28	600	600	1.67	1.81
19	1	2	0.78	1.29	284.91	251.82	600	600	1.76	1.76
33	1	3	1.45	1.38	191.20	216.18	580	580	1.56	1.80
34	1	3	0.62	1.07	245.33	244.65	606	600	1.61	1.75
35	1	3	0.59	0.95	209.08	263.81	600	600	1.52	1.79
4	2	1	0.81	0.68	293.69	271.57	550	475	1.30	1.76
5	2	1	0.52	1.25	186.78	445.15	550	550	1.21	1.75
6	2	1	0.39	0.62	221.06	198.83	550	600	1.27	1.85
20	2	2	0.62	0.74	257.40	320.18	550	550	1.22	1.86
21	2	2	0.61	0.50	228.74	248.84	550	520	1.20	1.80
22	2	2	0.87	0.48	256.78	326.32	550	530	1.31	1.81
36	2	3	0.67	0.55	230.43	282.15	550	525	1.30	1.76
37	2	3	0.86	0.77	227.19	221.93	550	550	1.32	1.76
38	2	3	0.57	0.52	188.73	231.80	550	600	1.24	1.85
7	3	1	0.44	0.34	222.90	220.90	550	620	1.80	1.83
8	3	1	0.47	1.19	204.44	205.15	550	580	1.81	1.70
9	3	1	0.64	0.76	227.43	223.45	550	540	1.90	1.76
23	3	2	0.58	0.64	237.24	189.11	550	550	1.89	1.75
24	3	2	0.95	0.61	251.01	195.96	550	550	1.80	1.81
25	3	2	0.67	0.44	272.37	221.62	560	600	1.80	1.76
39	3	3	0.65	0.71	248.48	228.94	550	580	1.90	1.84
40	3	3	0.70	1.04	278.23	236.46	550	500	2.00	1.88
41	3	3	0.46	0.49	263.39	228.26	550	590	1.80	1.78

NOTE: Tests 1 and 2 are the 0 and 4,000 mile data, respectively.

Table 4.1
(cont.)

Car No.	Make	Fuel	7-Mode CO Values in %		7-Mode HC Values in ppm		Idle RPM		PCV Flow (cu. ft./min.)	
			Test 1	Test 2	Test 1	Test 2	Test 1	Test 2	Test 1	Test 2
10	4	1	0.53	0.40	268.68	271.77	550	560	1.97	1.61
11	4	1	0.50	0.57	245.54	293.04	550	575	1.86	1.82
12	4	1	0.90	1.21	328.73	382.15	550	550	1.82	1.85
26	4	2	0.64	0.53	337.14	296.31	533	550	1.89	1.80
27	4	2	0.43	0.48	323.76	330.62	533	580	1.90	1.80
28	4	2	0.52	0.46	326.68	310.15	550	575	1.92	1.81
42	4	3	0.67	0.92	373.68	333.06	550	550	1.83	1.75
43	4	3	0.53	0.76	349.67	304.61	550	540	1.81	1.80
44	4	3	0.60	0.75	336.91	305.88	550	550	1.86	1.86
13	5	1	0.65	0.58	244.63	250.82	550	560	1.70	1.71
14	5	1	0.65	0.47	188.53	191.24	550	600	1.80	1.86
15	5	1	0.61	0.32	247.63	377.14	650	525	1.67	1.86
29	5	2	0.76	0.50	288.16	230.69	556	550	1.80	1.82
30	5	2	0.67	0.47	242.98	259.98	650	520	1.81	1.85
31	5	2	0.76	0.64	290.18	245.91	650	600	1.73	1.83
45	5	3	0.49	0.58	340.60	318.28	650	540	1.72	1.78
46	5	3	0.64	0.59	261.48	271.58	650	560	1.98	1.82
47	5	3	0.81	0.54	305.95	744.73	640	525	1.80	1.80
16	6	1	1.37	1.56	407.70	575.14	850	750	2.65	2.67*
32	6	2	1.15	1.06	475.87	171.21	850	880	2.98	2.30
48	6	3	1.83	1.73	354.99	452.48	850	1050	3.00	2.61

* VW PCV flowed @ 1" H_2O, all other valves flowed @ 18" Hg

NOTE: Tests 1 and 2 are the 0 and 4,000 mile data, respectively.

4.1 EXHAUST EMISSION DATA - continued

Table 4.2 contains the results of each of the nineteen three-factor (fuel, test interval, make) AOV's performed.

The calculated values of F listed in Appendix 6.4 were compared with those from an F-distribution table to determine the significance levels of the differences within factors and their interactions. Table 4.2 lists the significance level of the differences within each factor and interaction from the 95% to the 99.9% confidence levels. The differences in levels within the various factors were chosen to be significant only at the 95% confidence level or higher.

The initial test conducted in performing an analysis of variance is the F-test of a given factor or interaction effect. The F-test alone, however, indicates only the acceptance or rejection of the homogeneity hypothesis and does not indicate the homogeneous subsets that exist within the data set. A test commonly used to partition the data into subsets is the new multiple range test.* This test is based upon comparisons of individual mean values within factors. Table 4.3 contains the mean values for all significant factors. This test has been applied to the significant factors of fuel and make. A sample analysis procedure demonstrating the new multiple range test is incorporated in Appendix 6.3.

Fuel: Only two of the nineteen parameters tested, (HC, FID, 40) and (HC, NDIR, 40), showed significant differences between fuels at the 95% confidence level. The individual comparisons of the means within the

* Biometrics, March, 1955.

Table 4.2 Analysis of Variance Results
(0 and 4,000 Mile)

Emission Parameter	Significance at or above the Confidence Level Indicated (1)						
	Fuel	Interval	Make	Fuel x Interval	Fuel x Make	Interval x Make	Fuel x Interval x Make
7-Mode CO	-	0.95	0.999	-	-	0.999	-
7-Mode HC	-	-	0.99	-	-	-	-
Idle, RPM	-	-	0.999	-	-	0.999	-
PCV Flow	-	0.999	0.999	-	-	0.999	-
HC, FID, 20	-	0.95	-	-	-	-	-
HC, FID, 40	0.95	0.999	0.999	-	-	-	-
HC, FID, Idle	-	-	0.95	-	-	0.95	-
HC, NDIR, 20	-	-	0.999	-	0.99	-	-
HC, NDIR, 40	0.95	0.99	0.999	-	0.99	0.95	-
HC, NDIR, Idle	-	-	0.999	-	-	0.95	-
CO_2, 20	-	0.95	0.999	-	-	0.99	-
CO_2, 40	-	-	0.999	-	-	-	-
CO_2, Idle	-	0.999	0.999	-	-	0.999	-
CO, 20	-	0.95	0.999	-	-	0.99	-
CO, 40	-	-	0.999	-	-	-	-
CO, Idle	-	0.999	0.999	-	-	0.999	-
O_2, 20	-	-	0.99	-	-	-	-
O_2, 40	-	-	0.999	0.95	-	-	-
O_2, Idle	-	-	0.95	-	0.95	-	-

(1) Dashes indicate that calculated F-values are not significant at or above the 0.95 confidence level.

Table 4.3 Individual Comparisons of the Means for Significance Factors Shown in Table 4.2 (Listed in Ascending Order)

Emission Parameter	Mean Level (Fuel) (Note B)			Mean Level (Interval) (Note C)		Mean Level (Make) (Note D)				
7-Mode CO	(Note A)	-	-	0.645(1)	0.797(2)	0.60 (5)	0.63 (4)	0.65 (3)	0.67 (2)	1.05 (1)
7-Mode HC	-	-	-	-	-	231 (3)	251 (1)	258 (2)	294 (5)	318 (4)
Idle, RPM	-	-	-	-	-	547 (2)	552 (4)	559 (3)	585 (5)	601 (1)
PCV Flow	-	-	-	1.68 (1)	1.80 (2)	1.53 (2)	1.73 (1)	1.80 (5)	1.82 (3)	1.83 (4)
HC, FID, 20	-	-	-	406 (2)	458 (1)	-	-	-	-	-
HC, FID, 40	421(1)	447(3)	468(2)	415 (2)	475 (1)	328 (2)	417 (1)	432 (5)	482 (3)	567 (4)
HC, FID, Idle	-	-	-	-	-	399 (5)	430 (2)	435 (3)	512 (4)	561 (1)
HC, NDIR, 20	-	-	-	-	-	198 (3)	198 (1)	204 (2)	241 (4)	252 (5)
HC, NDIR, 40	184(1)	188(3)	204(2)	183 (1)	201 (2)	133 (2)	182 (1)	184 (5)	194 (3)	266 (4)
HC, NDIR, Idle	-	-	-	-	-	183 (5)	196 (3)	210 (2)	226 (1)	271 (4)
CO_2, 20	-	-	-	14.11(2)	14.38(1)	13.46(1)	13.95(5)	14.59(4)	14.62(2)	14.63(3)
CO_2, 40	-	-	-	-	-	14.51(1)	14.54(3)	14.62(5)	14.72(4)	14.78(2)
CO_2, Idle	-	-	-	13.05(2)	13.84(1)	12.56(1)	13.52(4)	13.67(2)	13.70(5)	13.77(3)
CO, 20	-	-	-	0.612(1)	0.886(2)	0.37 (3)	0.38 (2)	0.41 (4)	1.05 (5)	1.54 (1)
CO, 40	-	-	-	-	-	0.22 (2)	0.28 (4)	0.38 (5)	0.46 (3)	0.49 (1)
CO, Idle	-	-	-	1.16 (1)	1.95 (2)	1.23 (3)	1.30 (5)	1.33 (2)	1.48 (4)	2.44 (1)
O_2, 20	-	-	-	-	-	1.28 (1)	1.64 (3)	1.79 (2)	1.82 (5)	2.29 (4)
O_2, 40	-	-	-	-	-	1.64 (3)	1.73 (5)	2.43 (2)	2.72 (1)	2.72 (4)
O_2, Idle	-	-	-	-	-	0.95 (3)	1.00 (2)	1.10 (1)	1.20 (4)	1.62 (5)

NOTE: A = Dash lines indicate that the individual comparison of the means are not significant at the 0.95 level.
B = Number in parenthesis indicates Fuel Type.
C = Number in parenthesis indicates Interval; 1 = 0 Miles, 2 = 4,000 Miles.
D = Number in parenthesis indicates Make: Make 1 - Chev 327; Make 2 - Chev 250; Make 3 - Ford 302; Make 4 - Ford 390; Make 5 - Plym 318.

4.1 EXHAUST EMISSION DATA - continued

fuel factor are listed in Table 4.3 and are grouped by the new multiple range test as follows:

	Fuel Number		
HC, FID, 40	1	3	2
HC, NDIR, 40	1	3	2

For the HC, FID, 40 measurement, Fuels 1 and 3 are not significantly different from each other and Fuels 2 and 3 are also not different from each other. However, a grouping of Fuels 1 and 3 is significantly different from a grouping of Fuels 2 and 3. For the HC, NDIR, 40 variable, Fuels 1 and 3 mean levels are not significantly different. Fuel 2 (white additive) does, however, have a higher level than Fuels 1 and 3.

On the basis of this analysis, the conclusion is that at the 4,000-mile test interval, broad differences in the parameters tested with respect to the fuel factor are not apparent. However, if carburetor venturi and PCV deposits increase with further mileage accumulation, the significance of this factor will become more apparent.

Interval: Since there are data for only two test intervals, the significance levels indicate only a difference between the two levels. Treatment with the new multiple range test is therefore not required. The AOV's show nine parameters to be significantly different at the second test interval. These differences have been divided by category for discussion purposes as follows:

4.1 EXHAUST EMISSION DATA - continued

A. 7-Mode CO*
Idle CO
Steady State CO @ 20 MPH
Idle CO_2
Steady State CO_2 @ 20 MPH

B. PCV Flow Rates

C. Steady State HC by FID @ 20 MPH
Steady State HC by FID @ 40 MPH
Steady State HC by NDIR @ 40 MPH

Category A contains those related significant parameters associated with CO-CO_2 balance. These significances were all anticipated. The CO values increase with mileage and the CO_2 values decrease as the CO values increase. There are no anomalies connected with these data and a greater pronouncement of these effects is expected at the next test interval.

Category B, the PCV flow rates, show an unexpected trend with mileage. The overall average flow rate increased. The average flow for three Makes 1, 2, and 5 show an increase with mileage. Flows for Makes 3 and 4 show a decrease with mileage. These data will be carefully examined for a possible conclusive result at later test intervals.

Category C is composed of hydrocarbon concentration measurements. Some degree of anomalous behavior is apparent. The NDIR device indicates a significantly higher value of hydrocarbons at the 40-MPH steady state case at 4,000 miles. The FID device indicates a significantly lower value of hydrocarbons for the same case as well as the 20-MPH steady state case.

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* The average values of the parameters of all categories are shown in Table 4.3.

4.1 EXHAUST EMISSION DATA - continued

Table 4.3 shows the average values and indicates that the interval differences are minor when compared to the differences in the basic measurements. The FID instrument operates on an entirely different principle than does the NDIR instrument. The FID device basically counts all unoxidized carbon atoms, while the NDIR device counts only those hydrocarbons that are closely akin chemically to normal hexane. Therefore, the possibility does exist that these devices are not presenting anomalous data. A probable explanation of the effects seen here is that these vehicles are not yet truly stabilized with respect to hydrocarbon emissions. A gradual increase in the level of hydrocarbons is expected. This expected increase will probably be apparent at the next test interval and should be observable on both types of instrumentation.

Make: Table 4.2 shows that 18 of the 19 parameters reflect significance with respect to the make factor. Since the significance level was established at 95%, a misleading indication can be expected about 5% of the time. On this basis, all parameters vary significantly between makes. The new multiple range test has been utilized to examine this conclusion in somewhat greater detail. Table 4.4 shows the results of this examination. This examination makes apparent the fact that no single make is consistently the highest or lowest with respect to the nineteen parameters. If a single make were identifiable as the highest or lowest valued across the parameters, either a six-cylinder or the largest displacement eight-cylinder engine would be a reasonable expectation. However, no such identification is

Table 4.4 Results of the New Multiple Range Test on Make Factor Significances

	Lowest ← Values → Highest				
7-Mode CO	M_5	M_4	M_3	M_2	M_1
7-Mode HC	M_3	M_1	M_2	M_5	M_4
Idle RPM	M_2	M_4	M_3	M_5	M_1
PCV Flow Rate	M_2	M_1	M_5	M_3	M_4
Steady State HC (FID) @ 40 MPH	M_2	M_1	M_5	M_3	M_4
Steady State HC (FID) @ Idle	M_5	M_2	M_3	M_4	M_1
Steady State HC (NDIR) @ 20 MPH	M_3	M_1	M_2	M_4	M_5
Steady State HC (NDIR) @ 40 MPH	M_2	M_1	M_5	M_3	M_4
Steady State HC (NDIR) @ Idle	M_5	M_3	M_2	M_1	M_4
Steady State CO_2 @ 20 MPH	M_1	M_5	M_4	M_2	M_3
Steady State CO_2 @ 40 MPH	M_1	M_3	M_5	M_4	M_2
Steady State CO_2 @ Idle	M_1	M_4	M_2	M_5	M_3
Steady State CO @ 20 MPH	M_3	M_2	M_4	M_5	M_1
Steady State CO @ 40 MPH	M_2	M_4	M_5	M_3	M_1
Steady State CO @ Idle	M_3	M_5	M_2	M_4	M_1
Steady State O_2 @ 20 MPH	M_1	M_3	M_2	M_5	M_4
Steady State O_2 @ 40 MPH	M_3	M_5	M_2	M_1	M_4
Steady State O_2 @ Idle	M_3	M_2	M_1	M_4	M_5

4.1 EXHAUST EMISSION DATA - continued

possible. A conclusion is that: there is a significant difference between makes with respect to any given emission parameter, but there is no make that is significantly different across the spectrum of parameters.

Two-Way Factor Interactions: The two-way factor interactions are briefly discussed below. In general, the interpretations of the significances are similar to the interpretations assigned to the significant factors themselves. There are no anomalies.

Fuel x Interval: The only parameter indicating the Fuel x Interval factor interaction as significant is the steady state O_2 concentration at 40 MPH. This significance is at the lowest level, 95%, and is unsupportable from an analytical point of view. Arranging the mean values of the Fuel (F) x Interval (I) interaction from lowest to highest gives the following:

(F2 x I2)(F3 x I1)(F1 x I1)(F1 x I2)(F2 x I1)(F3 x I2)

There is no consistant pattern to this arrangement either by Fuel or Interval.

Differences in the Fuel x Interval factor interaction are hopefully to be apparent prior to the completion of the program.

Fuel x Make: Three parameters show a significant difference with respect to this interaction. These parameters are HC by NDIR at 40 MPH, HC by NDIR at 20, and steady state O_2 at Idle. The interactions for these parameters are listed below in order of descending magnitude of their mean values:

4.1 EXHAUST EMISSION DATA - continued

HC by NDIR at 40 MPH	HC by NDIR at 20 MPH	Steady State O_2 at Idle
F2 x M4	F3 x M5	F1 x M4
F3 x M4	F3 x M4	F3 x M5
F1 x M4	F2 x M5	F2 x M5
F2 x M1	F2 x M2	F1 x M5
F3 x M5	F2 x M4	F1 x M1
F1 x M3	F1 x M1	F1 x M2
F2 x M3	F2 x M5	F2 x M3
F2 x M5	F1 x M3	F2 x M1
F3 x M3	F1 x M4	F3 x M3
F3 x M1	F1 x M3	F3 x M1
F1 x M1	F1 x M1	F2 x M2
F1 x M5	F2 x M2	F3 x M2
F2 x M2	F3 x M3	F3 x M4
F1 x M2	F3 x M3	F1 x M3
F3 x M2	F3 x M1	F2 x M4

The order of the means of HC by NDIR at 40 Fuel x Make interactions indicates that these values have been heavily influenced by the make factor. The three highest valued means belong to Make #4 and the three lowest valued means belong to Make #2. The Fuel factor seems to be well distributed down the list.

Fuel x Make interaction means for HC by NDIR at 20 show some level of ordering by both Make and Fuel, but is by no means as evident as the ordering for HC by NDIR at 40 MPH.

The steady state O_2 at Idle Fuel x Make factor interaction means also show a degree of ordering with respect to both factors, i.e., Make #5 is grouped together at the high end of the scale, the rest of the Makes appear to be randomly distributed.

The significances shown by the three parameters with respect to the Fuel x Make factor interaction represent results that are consistant with the results obtained from analysis of the factors alone.

4.1 EXHAUST EMISSION DATA - continued

Interval x Make: Table 4.2 shows that ten parameters have significant differences with respect to this interaction. These interactions are shown in Table 4.5. The effects of the prime factors are clearly apparent in the arrangement of the interaction mean values for several of the parameters. For instance: all the hydrocarbon parameters reflect the Make factor strongly; whereas the CO and CO_2 parameters reflect the interval factor strongly. Table 4.5 demonstrates that there is no single Interval x Make interaction that is consistantly the highest or lowest valued, i.e., no Interval x Make pattern has been established at the 4,000 mile test point.

Three-Way Factor Interactions: None of the parameters reflects a three-way factor interaction as significant.

4.2 FUEL COMPOSITION DIFFERENCES

A series of tests were conducted to verify the hypothesis that fuel additives would not alter the fuel composition in a way that would affect exhaust emissions at the 0-mile interval. Twenty tests were conducted on a 1969 Chevrolet 327 CID, which is not in the 48 car test fleet, using Indolene 30 and Fuels 1, 2, and 3. Each test fuel was used during the test five different times in the random order shown in Table 4.6.

To establish temperature equilibrium, the car was warmed up for 15 minutes at 40-mph road load, and then driven through seven 7-mode cycles. The HC, (NDIR), CO, and CO_2 emissions were recorded on the last two cycles. Steady state exhaust emissions were also measured at 50-mph cruise and at idle.

Table 4.5 Interval x Make Interaction Significances

Parameter	Lowest ← Mean Values → Highest
Idle CO	(I1 x M2)(I1 x M1)(I1 x M3)(I2 x M5)(I2 x M3)(I1 x M4)(I2 x M2)(I2 x M4)(I2 x M1)(I1 x M5)
Steady State CO, 20 MPH	(I1 x M4)(I1 x M3)(I2 x M2)(I2 x M3)(I1 x M2)(I2 x M4)(I1 x M1)(I2 x M5)(I1 x M5)(I2 x M1)
7-Mode CO	(I2 x M5)(I1 x M4)(I1 x M3)(I1 x M2)(I1 x M5)(I2 x M4)(I2 x M2)(I1 x M1)(I2 x M3)(I2 x M1)
Steady State CO_2, Idle	(I2 x M1)(I2 x M4)(I2 x M2)(I1 x M5)(I2 x M3)(I2 x M5)(I1 x M4)(I1 x M3)(I1 x M1)(I1 x M2)
Steady State CO_2, 20 MPH	(I2 x M1)(I1 x M5)(I2 x M5)(I1 x M1)(I2 x M4)(I1 x M2)(I1 x M3)(I2 x M2)(I2 x M3)(I1 x M4)
Steady State HC FID, Idle	(I2 x M5)(I2 x M2)(I2 x M3)(I1 x M5)(I1 x M1)(I1 x M3)(I1 x M2)(I2 x M4)(I1 x M4)(I2 1 M1)
Steady State HC NDIR, 40	(I1 x M2)(I2 x M2)(I1 x M1)(I2 x M5)(I1 x M5)(I2 x M3)(I1 x M3)(I2 x M1)(I1 x M4)(I2 x M4)
Steady State HC NDIR, Idle	(I1 x M5)(I2 x M5)(I2 x M3)(I1 x M1)(I1 x M2)(I1 x M3)(I2 x M2)(I2 x M1)(I2 x M4)(I1 x M4)
PCV Flow	(I1 x M2)(I1 x M1)(I1 x M5)(I2 x M4)(I2 x M3)(I2 x M2)(I2 x M1)(I2 x M5)(I1 x M3)(I1 x M4)
Idle RPM	(I2 x M2)(I1 x M4)(I1 x M2)(I1 x M3)(I2 x M5)(I2 x M4)(I2 x M3)(I1 x M1)(I2 x M1)(I1 x M5)

Table 4.6 The Effect of Fuel Additives on
Exhaust Emissions at 0 Test Miles
1969 Chevrolet 327 CID, Auto. Trans.
(Not a Fleet Test Car)

Test No.	Test Fuel	Amb. Temp, °F	7-Mode Wtd Ems		Steady State (Corrected*) Idle		50 MPH, Cruise	
			HC, ppm	CO, %	HC, ppm	CO, %	HC, ppm	CO, %
1	Ind. 30	70	189	1.08	224	2.0	164	1.2
2	Ind. 30	70	227	1.29	256	2.6	195	1.2
3	2	73	244	0.98	297	1.9	258	1.2
4	2	75	247	1.01	265	1.5	184	1.0
5	1	78	249	0.94	247	2.4	212	1.7
6	3	74	222	0.76	245	1.3	199	1.2
7	3	70	261	0.89	257	2.0	221	1.3
8	2	70	233	1.02	246	2.1	207	1.2
9	1	68	276	0.89	315	2.3	266	1.2
10	3	68	276	0.94	260	2.3	240	1.1
11	2	70	250	0.79	265	1.7	230	1.1
12	Ind. 30	70	238	1.17	274	2.7	244	1.3
13	2	68	275	0.90	303	1.5	250	1.4
14	1	66	264	1.12	320	2.5	272	1.3
15	Ind. 30	76	302	1.16	346	2.5	293	1.5
16	3	80	289	1.00	344	1.9	274	1.3
17	1	74	254	1.02	313	1.9	238	1.3
18	Ind. 30	68	269	1.18	293	2.8	254	1.4
19	3	64	238	0.90	289	1.8	240	1.3
20	1	65	226	0.94	261	1.9	218	1.2

* $15/(CO + CO_2)$

4.2 FUEL COMPOSITION DIFFERENCES

After each test the fuel line was disconnected and the car was operated until it ran out of fuel. The car was soaked for at least 30 minutes before starting the next exhaust test. The next test fuel was then connected and the car was conditioned as described above prior to the exhaust test.

A statistical analysis was conducted on these data to determine the effect of fuel additives on the 7-mode weighted emissions. The data show that the additives for Fuel 2 and Fuel 3 do not alter the composition of the base fuel (Fuel 1) in a way that would influence emission levels on a test vehicle which had not previously used the test fuels.

4.3 CONCLUSIONS

The major conclusion is that: no significant differences in emission parameters were determined at the 4,000 mile point on the basis of fuel employed.

Secondary conclusions consist of: (A) except for the PCV flow rates, all parameters reflecting significance with respect to the Interval Factor behave as anticipated. Data for PCV flow ratio are to be examined at higher test intervals for possible additional conclusions; (B) all emissions parameters varied significantly between makes, however, no single make was consistently the highest or lowest or most extreme valued across the spectrum of the 19 parameters measured.

An observation with respect to the data from the Volkswagen vehicles was made. On the basis of the distinctly different data the Volkswagen was separated from the American-made vehicles and was not considered in this analysis.

APPENDIX 5.1 INITIAL SHOP PROCEDURES, FUEL ADDITIVES PROGRAM

Fleet control consists of fueling the vehicles as they accumulate mileage, the scheduling of exhaust tests, and scheduling maintenance services.

Fueling Vehicles During Mileage Accumulation: Fuel vehicles with assigned test fuel and record data on fuel record. Recap fuel data to individual vehicle fuel records and calculate cumulative mileage and fuel consumption.

Pickup and Delivery of Car: Determine correct odometer mileage for vehicle maintenance and exhaust tests. Telephone designated County personnel for pick up and delivery of the vehicle. Record the following data while car is in Scott's possession:

- o Fill in the instruction sheet (located on sun visor) with the odometer for next scheduled service or exhaust test.
- o Fill in appropriate data on individual vehicle service and test record.

Decal Installation: Install decals at the following locations:

Decal	Location
Engine Maintenance	Air Cleaner Top
Test Gasoline	Inside gas cap door or on the backside of license plates.
Test Oil	On or near oil fill cap.

The primary purpose of this program is to measure the effect of fuel additives on exhaust emissions. In order to measure the effect of additives on exhaust emissions, pre-emission tuneup procedures will consist

APPENDIX 5.1 INITIAL SHOP PROCEDURES, FUEL ADDITIVES PROGRAM - continued

of a "super tuneup" and servicing the car prior to exhaust testing and mileage accumulation. It is extremely important that all electrical, carburetion, and service items be adjusted correctly to manufacturer's specifications so that malfunctions will be kept to a minimum during mileage accumulation.

Fuel Tank Modification: Pump out tank gasoline and remove fuel tank and/or filler pipe. Install assigned fuel control "freeze plug" in vehicles as follows:

Car No.	Test Fuel Group	Test Fuel Color	Fuel Control Geometric Configuration
1-16	1	Red	□
17-32	2	White	○
33-48	3	Blue	◇

Reinstall tank, fill with specified test fuel, and install lock gas cap.

Lubrication and Oil Change: Lubricate, change oil, and install new oil filter in accordance with manufacturer's specifications. Use M2C48 motor oil from American Oil Company. This will be performed on all fleet vehicles for the first test. Subsequent lubrication and oil changes may be scheduled at different times than exhaust test mileage interval.

Electrical Tune Up: Conduct ignition system diagnosis with the Autoscan Ignition Analyzer. Record diagnosis as outlined on the Pre-Emission Test Tuneup Summary (see Appendix 5.2).

APPENDIX 5.1 INITIAL SHOP PROCEDURES, FUEL ADDITIVES PROGRAM - continued

Remove distributor and install new points and condensor. Check point dwell, mechanical advance, and vacuum advance systems for correct operation and adjustments in the Sun distributor machine. Install new spark plugs.

Record ignition system adjustments on the Pre-Emission Test Tuneup Summary (Appendix 5.2).

Carburetor Installation and Adjustments: Install new carburetor, and the PCV valve designated for a particular vehicle. Install new air filter element. Check the heat riser valve for correct operation.

Carburetor and Ignition Specifications: Following tuneup procedures, make "on car" adjustments to specifications shown in Table 1. Adjust throttle positioner as specified in shop manuals on Chevrolet 250 and VW's, and record on Pre-Emission Test Tuneup Summary.

EXHAUST EMISSIONS TEST PROCEDURES

Exhaust emissions tests will consist of 7-mode and steady state exhaust emission measurements. Idle adjustments are extremely critical and must be stabilized before proceeding with exhaust emission tests. Idle adjustments will be locked for 24,000 miles after exhaust testing is complete.

Idle Mixture Adjustment: Adjust car to idle speed and mixture specifications shown in Table 1 (References for idle mixture adjustment procedures are included). Run two 7-mode cycles to see if idle CO and speed

APPENDIX 5.1 INITIAL SHOP PROCEDURES, FUEL ADDITIVES PROGRAM - continued

returns to the initial adjustment. If not, readjust idle and run two more 7-mode cycles. Continue on with emissions tests if idle mixture and speed remains stable from cycle to cycle. Record carburetor adjustments on Pre-Emission Test Tune Up Summary.

Exhaust Emission Measurements: Measure HC (NDIR and FID), CO, CO_2, and O_2. Use tank test fuel for all tests. The mass flow system will not be used during emission tests.

Precondition vehicle (after idle mixture adjustment) at 40 MPH for 15 minutes. Run four (4) 7-mode cycles and record emissions of the last 2 cycles.

Measure steady state emissions listed above at the following conditions in the order listed:

Precondition	Test Condition
3 minutes	20 MPH, road load
3 minutes	40 MPH, road load
1 minute	Idle in drive

Measure emissions for 15 seconds at each condition after pre-conditioning.

Record all pertinent exhaust emission data on Exhaust Emission Summary for Data Processing (Figure 2).

POST TEST PROCEDURES

Idle Mixture and Speed: In order to prevent idle adjustments being made by the driver in the field, lock both idle mixture and idle speed screws with epoxy, jam nuts, safety wiring, or "shields."

APPENDIX 5.1 INITIAL SHOP PROCEDURES, FUEL ADDITIVES PROGRAM - continued

Check pre-emission test tuneup summary and exhaust emission summary sheet for completeness before delivering vehicle.

Insert all data sheets in vehicle file.

A = Adjust
R = Replace

Scott Research Labs., Inc.
Project #2807

April 30, 1970

APPENDIX 5.2 PRE EMISSION TEST TUNEUP SUMMARY

Car # 6 Odo 3,735 , miles Car Make Chevrolet

Engine CID 250 Total Diagnosis Time _____ hrs. Total Tuneup Time _____ hrs.

IGNITION SYSTEM	DIAGNOSIS	Checked By
Firing Line	OK	
o Required Voltage, kv	5-7	
o Coil Available Voltage, kv		
Spark Line	OK	
Coil Oscillations	OK	
Cond. Oscillations	OK	
Points Opening	OK	
Points Closing	OK	
Dynamic Compression (speed change ")	1 10.5 2 9 3 9 4 9.5 5 11 6 9 7 ____ 8 ____	

IGNITION SYSTEM ADJUSTMENTS	As Rec'd	Spec.	Adj (A) or Replace (R)	
Spark Plug Gap, inches		.035	R - .035	
Ignition Point Dwell, distr. degrees		31°-34°	32.5°	
Ignition Timing, crankshaft degrees		4° BTC	4° BTC	
Total Advance, crankshaft degrees	49°			
Mechanical Advance, crankshaft degrees	27°			
Vacuum Advance, crankshaft degrees	22°			

APPENDIX 5.2 PRE EMISSION TEST TUNEUP SUMMARY - continued

CARBURETOR ADJUSTMENTS	As Rec'd	Spec.	Adj (A) or Replace (R)	Checked By
Idle RPM, Drive/Vacuum, in. Hg	590/14.0	550 D	550 D	
Idle RPM, Neutral/Vacuum, in. Hg	730/16.0		690/14.5	
Idle RPM (throttle positioner off)				
Idle CO, %/AF Ratio	3.2		1.0	
Exhaust CO @ 2500 RPM, Neutral	0.3		0.3	

AIR CLEANER

Element Condition, AC Tester			R	
Thermostatic Intake Opening Temp, °F			100°	

EXHAUST CONTROL VALVE	Frozen Closed	Frozen Open	Free	
Heat Riser Valve Operation			X	

APPENDIX 5.3 CARBURETOR SPECIFICATION SHEET

Car Make Chevrolet Year 1969 Model Chevelle - Malibu Engine CID 250

Carb. # 7029014 Carb. Type: 2BB ✓ 4 BB ___ Date 4-22-69

Project # 2807-03 Car # 6

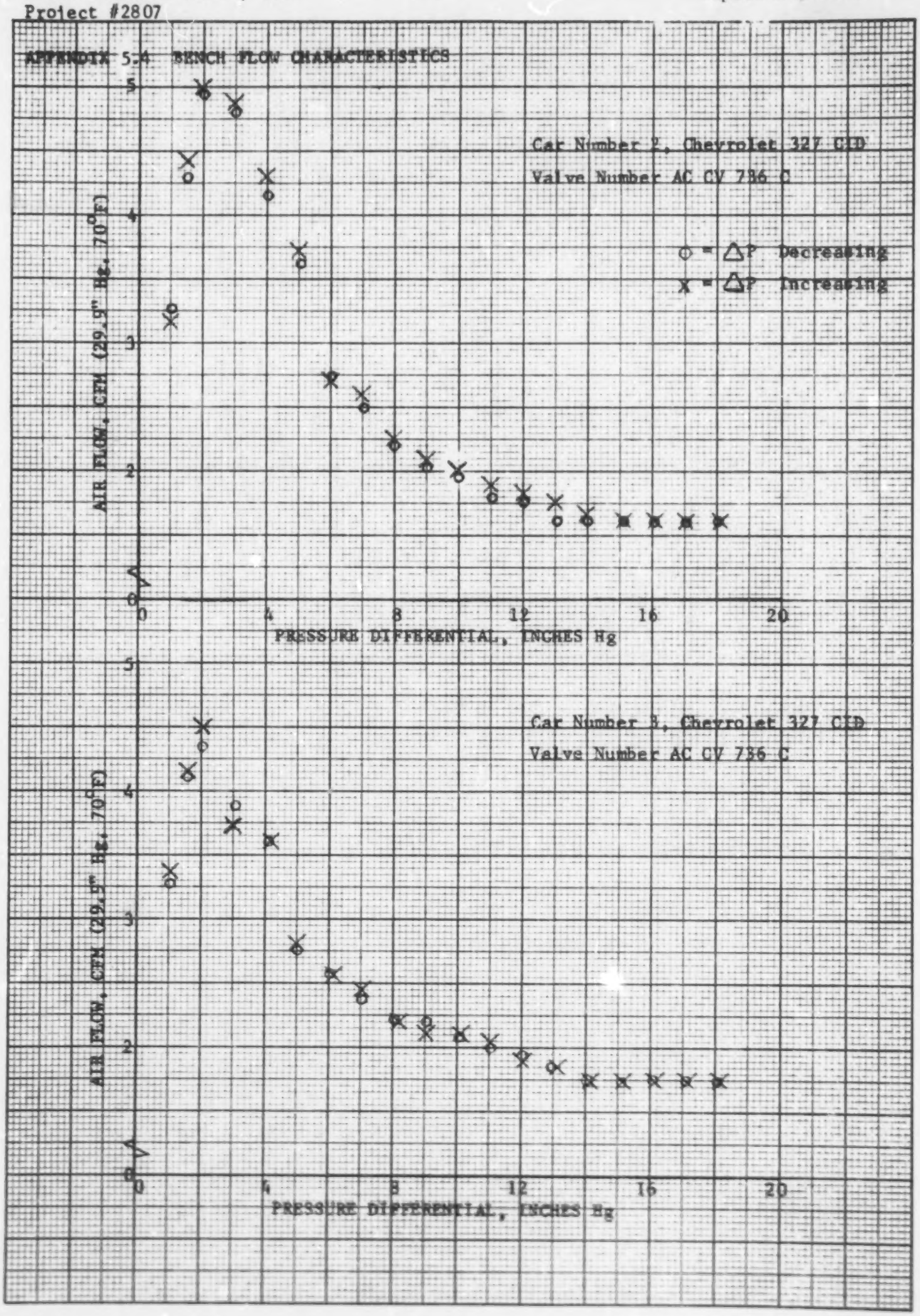
	Was	Spec's	Set To
Float Level, Primary	3/16"	1/4"	1/4"
Float Level, Secondary		—	
Float Drop, Primary		—	
Float Drop, Secondary		—	
Main Metering Jets, Primary		.104	
Main Metering Jets, Secondary		—	
Metering Rods, First Stage	.078	.070	.070
Metering Rods, Second Stage		—	
Accelerator Pump Stroke		—	
Idle-Bowl-Vent	.046	.050	.050
Choke Type	—	Wall Thermostatic	—
Choke Setting	.190	.170	.170
Choke Vacuum Break or Kick	.266	.245	.245
Choke Unloader	.375	.350	
Fast Idle Mechanical / Running	.081	.100 / 2400	.100
Idle Speed - RPM	D / N	D / N	D / N
Idle Mixture Screws Turns Open			

Remarks: _____

_____

SRS-151

APPENDIX 5.4 BENCH FLOW CHARACTERISTICS



APPENDIX 5.5 Test Fleet Identification
Project #2807
Fuel Number One (1), Code RED

Car No.	Make	Model	Engine CID	Air Cond.	Vehicle Source	SB County ID or Lic. No.	SB County Dept.	Carburetor Make & Number	PCV Valve
1	Chev.	Biscayne	327	Yes	SB Co.	1008	Co. Counsel	7029, 104	736
2	Chev.	Biscayne	327	No	SB Co.	1389	Welfare	7029, 102	736
3	Chev.	Biscayne	327	No	SB Co.	1419	Probation	7029, 102	736
4	Chev.	Chevelle	250	Yes	Scott	13537 9Z333387 XBB-276	Bldg. & Safety	7029, 014	723
5	Chev.	Chevelle	250	Yes	Scott	13537 9Z333452 XBB-777	Bldg. & Safety	7029, 014	723
6	Chev.	Chevelle	250	Yes	Scott	13537 9Z333413 XBB-778	Bldg. & Safety	7029, 014	723
7	Ford	Galaxie 500	390	Yes	Scott	9J55Y158079 XBB-924	Admin. Office	C9AF,9510C	EV-8
8	Ford	Galaxie 500	390	Yes	Scott	9J55Y158078 XBB-925	Marshall	C9AF,9510C	EV-8
9	Ford	Galaxie 500	390	Yes	Scott	9J55Y156223 XBB-926	Marshall	C9AF,9510C	EV-8
10	Ford	Custom	302	No	SB Co.	1058	Planning	C9AF,9510A	EV-8
11	Ford	Custom	302	No	SB Co.	1059	Planning	C9AF,9510A	EV-8
12	Ford	Custom	302	No	SB Co.	1375	Welfare	C9AF,9510A	EV-8
13	Plym	Fury I	318	Yes	SB Co.	1299	Agriculture	4608 S	L 351
14	Plym	Fury I	318	Yes	SB Co.	1046	Economic Dev.	4608 S	L 351
15	Plym	Fury I	318	Yes	SB Co.	1062	Planning	4608 S	L 351
16	VW	1131 Sedan	78	No	Scott	119337178 XBB-297	Admin. Office	VW 126-2	

APPENDIX 5.5 Test Fleet Identification
Project #2807
Fuel Number Two (2), Code WHITE

Car No.	Make	Model	Engine CID	Air Cond.	Vehicle Source	SB County ID or Lic. No.	SB County Dept.	Carburetor Make & Number	PCV Valve
17	Chev.	Biscayne	327	Yes	SB Co.	1009	Admin. Office	7029, 104	736
18	Chev.	Biscayne	327	No	SB Co.	4494	Marshall	7029, 102	736
19	Chev.	Biscayne	327	No	SB Co.	1010	Admin. Office	7029, 102	736
20	Chev.	Chevelle	250	Yes	Scott	13537 9Z333393 XBB-779	Bldg. & Safety	7029, 014	723
21	Chev.	Chevelle	250	Yes	Scott	13537 9Z333409 XBB-780	Bldg. & Safety	7029, 014	723
22	Chev.	Chevelle	250	Yes	Scott	13537 9Z333399 XBB-781	Bldg. & Safety	7029, 014	723
23	Ford	Galaxie 500	390	Yes	Scott	9J55Y157329 XBB-927	Marshall	C9AF,9510C	EV-8
24	Ford	Galaxie 500	390	Yes	Scott	9J55Y156221 XBB-928	Admin. Office	C9AF,9510C	EV-8
25	Ford	Galaxie 500	390	Yes	Scott	9J55Y157330 XBB-929	Marshall	C9AF,9510C	EV-8
26	Ford	Custom	302	No	SB Co.	1376	Welfare	C9AF,9510A	EV-8
27	Ford	Custom	302	No	SB Co.	1378	Welfare	C9AF,9510A	EV-8
28	Ford	Custom	302	No	SB Co.	1379	Welfare	C9AF,9510A	EV-8
29	Plym	Fury I	318	Yes	SB Co.	1049	Economic Dev.	4608 S	L 351
30	Plym	Fury I	318	Yes	SB Co.	1005	Admin. Office	4608 S	L 351
31	Plym	Fury I	318	Yes	SB Co.	1007	Admin. Office	4608 S	L 351
32	VW	1131 Sedan	78	No	Scott	119369646 XBB-299	Communications	VW 126-2	

APPENDIX 5.5 Test Fleet Identification
Project #2807
Fuel Number Three (3), Code BLUE

Car No.	Make	Model	Engine CID	Air Cond.	Vehicle Source	SB County ID or Lic. No.	SB County Dept.	Carburetor Make & Number	PCV Valve
33	Chev.	Biscayne	327	Yes	SB Co.	1031	D.A. Domestic Relations	7029, 104	736
34	Chev.	Biscayne	327	No	SB Co.	1421	Probation	7029, 102	736
35	Chev.	Biscayne	327	No	SB Co.	1423	Probation	7029, 102	736
36	Chev.	Chevelle	250	Yes	Scott	13537 9Z333434 XBB-782	Bldg. & Safety	7029, 014	723
37	Chev.	Chevelle	250	Yes	Scott	13537 9Z333446 XBB-783	Admin. Office Temporary	7029, 014	723
38	Chev.	Chevelle	250	Yes	Scott	13537 9Z333406 XBB-310	Admin. Office Gen. Hospital	7029, 014	723
39	Ford	Custom	390	Yes	SB Co.	1274	APCD Air Pollution	C9AF,9510C	EV-8
40	Ford	Custom	390	Yes	SB Co.	1461	APCD Air Pollution	C9AF,9510C	EV-8
41	Ford	Custom	390	Yes	SB Co.	1289	Agriculture	C9AF,9510C	EV-8
42	Ford	Custom	302	No	SB Co.	1380	Welfare	C9AF,9510A	EV-8
43	Ford	Custom	302	No	SB Co.	1387	Welfare	C9AF,9510A	EV-8
44	Ford	Custom	302	No	SB Co.	1388	Welfare	C9AF,9510A	EV-8
45	Plym	Fury I	318	Yes	SB Co.	1348	Health	4608 S	L 351
46	Plym	Fury I	318	Yes	SB Co.	1349	Health	4608 S	L 351
47	Plym	Fury I	318	Yes	SB Co.	1363	Health	4608 S	L 351
48	VW	1131 Sedan	78	No	Scott	119338135 XBB-298	Admin. Office Temporary	VW 126-2	

APPENDIX 5.6 TEST FUEL ANALYSES

	MS08 Spec	Am. Oil	Batch 1			Batch 2			Batch 3		
			Red	White	Blue	Red	White	Blue	Red	White	Blue
Gravity, °API	-	58.1	57.7	57.2	57.7	57.3	57.2	57.1	59.2	58.8	58.6
Lead Content, g/gal.	-	-	3.16	3.16	3.19	3.15	3.17	3.17	3.21	3.17	3.16
Sulfur, % by wt.	0.075-0.10	0.11	0.132	0.128	0.131	0.128	0.118	0.131	-	-	-
Reid Vapor Press, psi	9.5 max	8.5	-	-	-	8.4	8.4	8.3	9.5	9.4	9.2
Distillation											
Initial Boil Pt, °F	-	-	98	100	96	94	95	96	90	91	92
10% Evap., °F	110-135	119	127	127	123	123	124	126	122	122	123
50% Evap., °F	200-235	223	229	229	225	224	224	228	206	210	212
90% Evap., °F	330-365	345	355	356	354	348	354	352	341	346	347
Final Boil Pt, °F	415 max	396	414	412	400	408	410	407	418	421	416
Recovery, %	-	98.0	98.0	98.0	98.0	98.0	98.0	98.0	97.5	97.5	97.5
Loss, %	-	-	1.0	0.9	0.8	1.1	0.9	0.9	1.6	1.5	1.5

NOTE: 1. Red, White, and Blue fuel test results from Ethyl Corporation.
2. Blank spaces indicate that data were not reported.

APPENDIX 5.7 FUEL AND MILEAGE RECORD

Colors	Fuel #	Car Nos.
Red	1	1-16
White	2	17-32
Blue	3	33-48

Car # 6 Fuel # 1 Color Code RED

Odometer, Miles				Fuel Quantity, Gal.		Fuel Consumption, mpg	
Date	Actual	Net/ Tank	Cumulative to Date	Per Tank	Total To Date	Per Tank	Avg. to Date
4-2-69	623	—	—	—	—	—	—
4-7-69	865	242	242	16.7ga.	16.7	14.5	14.5
4-11-69	1110	245	487	15.0	31.7	16.3	15.4
4-16-69	12929	182.9	669.9	13.0	44.7	14.1	15.0
4-21-69	14763	1834	85533	12.3	57.0	14.9	15.0
5-5-69	1670.	193.7	1047.0	14.8	71.8	13.1	14.6
5-6-69	1835.0	165.0	1212.0	11.0	82.8	15.0	14.6

Scott Research Labs., Inc.
Project #2807

April 30, 1970

APPENDIX 5.8 IGNITION KNOCK SURVEY RESULTS

Car No.	Make/CID	20-60 MPH Accel. None	BL*	Above BL	40 MPH Cruise None	BL*	Above BL	Ignition Timing, Degrees As Received Meas.	Spec.	Variation From Spec.	Point Dwell, Degrees** Spec. Range	0 Test Miles	4,000 Mile Test	Variation From Spec. 4,000 mi.
1	Chev. 327			x	x			+4	+2	+2	28-32	28	26	-2.0
2	Chev. 327		x		x			+2	+2	0	28-32	28	30	0
3	Chev. 327	x			x			+2	+2	0	28-32	29	29	0
4	Chev. 250	x			x			+3	+4	-1	31-34	33	34	0
5	Chev. 250	x			x			+4	+4	0	31-34	31	31	0
6	Chev. 250	x			x			+4	+4	0	31-34	32.5	32	0
7	Ford 390		x		x			+6	+6	0	26-31	26	31	0
8	Ford 390		x		x			+6	+4	+2	26-31	29	31.5	+0.5
9	Ford 390		x		x			+2	+6	-4	26-31	27	31	0
10	Ford 302	x			x			0	+6	-6	-	-	-	-
11	Ford 302		x		x			0	+6	-6	26-31	28	32	+1.0
12	Ford 302		x		x			+4	+6	-2	26-31	27	28.5	0
13	Plym. 318	x			x			0	0	0	30-35	30.5	27	-3.0
14	Plym. 318			x	x			+2	0	+2	30-35	30	25	-5.0
15	Plym. 318	x			x			0	0	0	-	-	-	-
16	VW 78	x			x			-1	0	-1	-	-	-	-
17	Chev. 327			x	x			+2	+2	0	28-32	28	28	0
18	Chev. 327		x		x			+2	+2	0	28-32	31	30	0
19	Chev. 327			x	x			+3	+2	+1	-	-	-	-
20	Chev. 250	x			x			+5	+4	+1	31-34	34	35	+1.0

* Borderline
** Blank spaces indicate that the 4,000 mile test had not been conducted as of October 2, 1969.

APPENDIX 5.8 IGNITION KNOCK SURVEY RESULTS - continued

Car No.	Make/CID	20-60 MPH Accel. None	20-60 MPH Accel. BL*	20-60 MPH Accel. Above BL	40 MPH Cruise None	40 MPH Cruise BL*	40 MPH Cruise Above BL	Ignition Timing, Degrees As Received Meas.	Ignition Timing, Degrees As Received Spec.	Ignition Timing, Degrees Variation From Spec.	Point Dwell, Degrees** Spec. Range	Point Dwell, Degrees** 0 Test Miles	Point Dwell, Degrees** 4,000 Mile Test	Point Dwell, Degrees** Variation From Spec. 4,000 mi.
21	Chev. 250	x			x			+2	+4	-2	31-34	31	32	0
22	Chev. 250	x			x			+4	+4	0	31-34	33.5	34	0
23	Ford 390		x		x			+2	+6	-4	26-31	26	28	0
24	Ford 390	x			x			0	+6	-6	26-31	28	34	+3.0
25	Ford 390	x			x			0	+6	-6	26-31	30	41	+10.0
26	Ford 302	x			x			+3	+6	-3	26-31	29	34	+3.0
27	Ford 302	x			x			+2	+6	-4	26-31	29	29	0
28	Ford 302		x		x			+2	+6	-4	26-31	28	30	0
29	Plym. 318	x			x			+4	0	+4	30-35	33	34.5	0
30	Plym. 318	x			x			+1	0	+1	30-35	30	28	-2
31	Plym. 318		x		x			0	0	0	30-35	29.5	31	0
32	VW 78	x			x			-1	0	-1	-	-	-	-
33	Chev. 327		x		x			+2	+2	0	-	-	-	-
34	Chev. 327	x			x			+2	+2	0	-	-	-	-
35	Chev. 327		x		x			+2	+2	0	28-32	30	31	0
36	Chev. 250	x			x			+2	+4	-2	-	-	-	-
37	Chev. 250	x			x			+4	+4	0	31-34	31	34	0
38	Chev. 250		x		x			+5	+4	+1	31-34	33.5	33	0
39	Ford 390	x			x			+2	+6	-4	26-31	28.5	31	0
40	Ford 390		x		x			+9	+6	+3	26-31	30	26	0

* Borderline
** Blank spaces indicate that the 4,000 mile test had not been conducted as of October 2, 1969.

APPENDIX 5.8 IGNITION KNOCK SURVEY RESULTS - continued

Car No.	Make/CID	20-60 MPH Accel. None	BL*	Above BL	40 MPH Cruise None	BL*	Above BL	Ignition Timing, Degrees As Received Meas.	Spec.	Variation From Spec.	Point Dwell, Degrees** Spec. Range	0 Test Miles	4,000 Mile Test	Variation From Spec. 4,000 mi.
41	Ford 390	x			x			+2	+6	-4	-	-	-	-
42	Ford 302		x		x			+2	+6	-4	26-31	30	29	0
43	Ford 302			x	x			+4	+6	-2	26-31	28	29	0
44	Ford 302	x			x			+2	+6	-4	26-31	27.5	32	+1.0
45	Plym. 318			x			x	+2	0	+2	-	-	-	-
46	Plym. 318			x			x	+3	0	+3	30-35	31	31	0
47	Plym. 318	x			x			0	0	0	-	-	-	-
48	VW 78	x			x			-1	0	-1	-	-	-	-

* Borderline
** Blank spaces indicate that the 4,000 mile test had not been conducted as of October 2, 1969.

Ignition Knock Distribution (20-60 MPH Accel.)

Fleet Summary		Summary by Make	
None	54%	8 Chev.	36%
BL	31%	10 Ford	45%
Above BL	15%	4 Plym.	19%
	100%		100%

Scott Research Labs., Inc.
Project #2807

April 30, 1970

APPENDIX 6.1 TEST DATA AT 0 TEST MILE
All Data are average of test Numbers 1, 2, and 3

Car No.	Start Miles	Idle RPM	PCV Flow CFM	7-Mode Wtd Ems CO, %	7-Mode Wtd Ems HC ppm	Corrected Steady State Emissions: HC, ppm (FID) Idle	20	40	HC, ppm (NDIR) Idle	20	40	CO_2, % Idle	20	40	CO, % Idle	20	40	Oxygen Idle	20	40
1	5,869	600	1.70	0.75	211	439	474	476	184	213	182	13.9	14.5	14.3	1.11	0.47	0.67	1.28	1.93	1.45
2	3,146	600	1.61	0.45	233	428	361	411	192	157	168	14.1	14.2	14.8	1.29	0.77	0.19	2.16	2.55	3.00
3	9,812	600	1.75	0.56	241	406	430	374	161	178	139	14.0	14.0	14.8	0.98	0.98	0.23	1.01	0.95	3.32
4	4,163	550	1.30	0.80	293	488	436	387	231	253	144	13.5	14.8	14.8	1.46	0.22	0.22	0.86	2.18	2.25
5	3,948	550	1.21	0.52	187	461	370	400	170	146	118	13.9	14.8	14.8	1.12	0.22	0.22	0.95	2.39	1.75
6	3,730	550	1.27	0.39	221	464	355	358	182	160	139	14.4	14.4	14.8	0.58	0.64	0.22	1.14	2.16	2.58
7	3,188	550	1.80	0.44	221	452	450	507	201	219	210	14.2	14.6	14.8	0.82	0.38	0.22	1.06	1.28	2.16
8	4,530	550	1.81	0.47	204	412	366	455	180	164	169	14.3	14.8	14.8	0.71	0.22	0.23	0.89	1.65	1.90
9	5,252	550	1.90	0.63	227	497	514	547	204	229	218	13.8	14.5	14.1	1.16	0.47	0.86	0.82	1.32	0.80
10	4,869	550	1.97	0.53	268	562	339	520	308	181	242	13.6	14.7	14.8	1.41	0.30	0.23	2.77	2.43	3.02
11	7,907	550	1.86	0.49	245	478	393	552	206	163	307	14.0	14.8	14.8	1.04	0.21	0.23	0.97	2.15	2.86
12	4,623	550	1.82	0.90	328	534	514	664	301	243	276	13.7	14.4	14.8	1.29	0.62	0.23	1.73	1.28	2.19
13	4,057	550	1.70	0.65	244	396	472	426	189	250	166	13.8	14.5	14.8	1.16	0.51	0.23	1.41	1.58	1.88
14	2,962	550	1.80	0.65	188	387	477	384	130	216	95	13.4	14.0	14.8	1.59	0.99	0.23	2.06	1.42	2.26
15	3,500	650	1.67	0.60	247	389	454	479	182	199	177	13.6	13.8	14.4	1.39	1.16	0.65	1.19	1.47	1.19
16	3,548	850	2.65*	1.37	407	409	340	301	177	222	184	12.4	14.4	14.1	2.62	0.65	0.88	0.69	1.84	0.84

* VW's flow measured at 1 inch H_2O Δ P. All others measured at 18" Hg.

APPENDIX 6.1 TEST DATA AT 0 TEST MILE
All Data are average of test Numbers 1, 2, and 3

Car No.	Start Miles	Idle RPM	PCV Flow CFM	7-Mode Wtd Ems CO, %	7-Mode Wtd Ems HC ppm	Corrected Steady State Emissions: HC, ppm (FID) Idle	HC, ppm (FID) 20	HC, ppm (FID) 40	HC, ppm (NDIR) Idle	HC, ppm (NDIR) 20	HC, ppm (NDIR) 40	CO_2, % Idle	CO_2, % 20	CO_2, % 40	CO, % Idle	CO, % 20	CO, % 40	Oxygen Idle	Oxygen 20	Oxygen 40
17	4,118	600	1.70	0.50	260	383	336	413	176	178	175	14.4	14.5	14.8	0.59	0.50	0.25	2.17	1.93	3.51
18	3,843	600	1.67	0.48	233	478	368	370	215	178	158	14.1	14.3	14.8	0.93	0.69	0.25	0.82	1.53	3.42
19	3,892	600	1.76	0.78	288	519	481	505	242	231	221	13.8	14.1	14.4	1.23	0.89	0.61	0.76	1.15	2.84
20	4,402	550	1.22	0.62	257	481	452	357	229	272	121	13.6	14.0	14.8	1.44	0.96	0.23	0.82	1.25	2.58
21	3,690	550	1.20	0.61	228	454	421	298	195	222	103	14.1	14.8	14.8	0.87	0.23	0.23	1.22	1.92	2.53
22	3,783	550	1.31	0.87	256	572	545	401	241	244	102	13.6	14.5	14.8	1.37	0.48	0.23	0.98	1.51	2.74
23	4,283	550	1.89	0.58	237	523	470	670	232	165	188	13.2	14.8	14.8	1.81	0.23	0.23	1.11	2.84	2.61
24	4,422	550	1.80	0.95	251	438	487	527	193	225	212	14.0	14.6	14.0	1.04	0.39	1.01	0.91	1.59	1.67
25	5,300	560	1.80	0.67	272	471	447	550	194	198	204	13.9	14.1	14.4	1.13	0.86	0.59	0.96	1.07	1.26
26	5,846	533	1.89	0.63	337	562	425	620	280	211	271	13.9	14.6	14.8	1.09	0.45	0.24	0.67	1.90	2.93
27	4,870	533	1.90	0.43	323	494	379	588	262	199	259	14.1	14.8	14.8	0.93	0.24	0.24	0.75	2.99	2.87
28	4,734	550	1.92	0.51	326	514	577	591	247	367	251	13.9	14.8	14.8	1.14	0.23	0.23	0.76	2.80	2.91
29	3,538	557	1.80	0.75	288	472	458	510	225	249	224	13.3	13.9	14.2	1.67	1.12	0.76	2.78	1.65	1.63
30	3,817	650	1.81	0.67	243	461	487	482	153	211	170	13.6	13.4	14.8	1.45	1.64	0.25	1.11	2.19	1.74
31	2,892	650	1.73	0.76	290	427	520	461	185	317	198	13.7	14.1	14.7	1.28	0.90	0.33	1.06	1.40	1.22
32	4,696	850	2.98*	1.14	476	523	456	378	251	274	177	13.7	13.8	14.4	1.32	1.17	0.64	1.36	2.16	1.21

* VW's flow measured at 1 inch H_2O Δ P. All others measured at 18" Hg.

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Scott Research Labs., Inc.
Project #2807

April 30, 1970

APPENDIX 6.1 TEST DATA AT 0 TEST MILE
All Data are average of test Numbers 1, 2, and 3

Car No.	Start Miles	Idle RPM	PCV Flow CFM	7-Mode Wtd Ems CO, %	7-Mode Wtd Ems HC ppm	Corrected Steady State Emissions HC, ppm (FID) Idle	20	40	HC, ppm (NDIR) Idle	20	40	CO_2, % Idle	20	40	CO, % Idle	20	40	Oxygen Idle	20	40
33	3,365	580	1.56	1.45	191	530	449	464	172	172	154	13.5	13.4	14.3	1.48	1.58	0.73	0.94	0.91	1.40
34	2,640	607	1.61	0.61	245	511	389	414	225	159	153	13.9	14.2	14.0	1.14	0.82	1.04	0.81	1.02	2.56
35	8,602	600	1.52	0.59	209	408	414	406	146	141	129	13.9	14.3	14.8	1.11	0.72	0.24	1.05	1.38	3.98
36	4,650	550	1.30	0.67	244	481	528	340	191	217	86	14.4	14.6	14.8	0.65	0.43	0.23	1.18	1.58	2.71
37	3,272	550	1.32	0.86	227	417	311	287	192	199	89	14.0	14.8	14.7	0.96	0.22	0.29	1.10	2.91	1.85
38	5,085	550	1.24	0.57	189	449	378	292	197	162	75	14.1	14.8	14.8	0.87	0.23	0.24	1.01	2.53	3.20
39	4,197	550	1.90	0.65	248	436	447	493	219	244	206	13.7	14.8	14.5	1.28	0.22	0.51	0.73	1.59	1.24
40	4,978	550	2.00	0.70	278	510	466	479	254	232	209	13.7	14.8	14.8	1.29	0.22	0.22	0.65	1.75	1.50
41	4,197	550	1.80	0.46	263	398	412	456	191	197	181	14.2	14.8	14.5	0.85	0.18	0.46	0.64	2.01	1.31
42	4,868	550	1.83	0.67	374	557	595	608	280	328	272	13.6	14.7	14.8	1.43	0.26	0.23	0.82	2.15	2.27
43	4,835	550	1.81	0.52	350	560	583	613	292	331	267	14.0	14.7	14.8	1.01	0.27	0.24	0.83	2.25	2.53
44	4,949	550	1.86	0.60	336	537	641	626	296	358	282	13.7	14.8	14.8	1.31	0.23	0.23	1.00	2.79	2.55
45	3,357	650	1.72	0.49	341	560	620	577	263	298	217	13.9	14.1	14.8	1.13	0.89	0.22	1.87	1.75	1.75
46	5,753	650	1.98	0.64	261	368	553	511	149	250	202	13.4	13.9	14.6	1.63	1.14	0.39	2.05	2.25	1.60
47	4,423	650	1.80	0.81	306	367	567	538	161	302	209	13.6	12.9	14.2	1.36	2.13	0.81	1.52	1.10	1.07
48	3,500	850	3.00*	1.82	355	406	332	338	143	184	146	12.3	14.8	13.6	2.68	0.25	1.38	3.72	1.95	0.69

* VW's flow measured at 1 inch H_2O Δ P. All others measured at 18" Hg.

Scott Research Labs., Inc.
Project #2807

April 30, 1970

APPENDIX 6.2 TEST DATA AT 4,000 TEST MILE

Car No.	Actual Test Miles	Idle RPM	PCV Flow CFM	7-Mode Wtd Ems CO, %	7-Mode Wtd Ems HC ppm	Corrected Steady State Emissions: HC, ppm (FID) Idle	HC, ppm (FID) 20	HC, ppm (FID) 40	HC, ppm (NDIR) Idle	HC, ppm (NDIR) 20	HC, ppm (NDIR) 40	CO_2, % Idle	CO_2, % 20	CO_2, % 40	CO, % Idle	CO, % 20	CO, % 40	Oxygen Idle	Oxygen 20	Oxygen 40
1	5,024	620D	1.82	1.57	245	534	438	375	262	205	188	10.8	12.1	14.6	4.23	2.89	0.42	0.55	0.56	1.46
2	4,393	580D	1.85	1.90	276	729	541	447	297	253	218	8.9	11.2	14.8	6.10	3.82	0.21	0.59	0.53	2.23
3	4,386	620D	1.80	0.90	190	412	253	117	216	146	96	11.5	13.5	14.8	3.47	1.46	0.21	2.06	2.24	3.62
4	4,032	475D	1.76	0.68	272	-	-	-	223	193	142	12.7	14.8	14.8	2.32	0.22	0.22	-	-	-
5	3,931	550D	1.75	1.25	445	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	4,038	600D	1.85	0.62	199	416	355	344	218	188	161	13.2	14.7	14.8	1.84	0.30	0.21	1.16	1.62	2.60
7	3,998	620D	1.83	0.34	221	360	383	401	195	221	211	14.2	14.6	14.6	0.80	0.40	0.42	0.90	1.11	1.58
8	4,950	580D	1.70	1.19	205	410	344	500	180	151	182	13.6	14.2	14.4	1.40	0.83	0.62	0.60	1.04	1.04
9	4,130	540D	1.76	0.76	223	458	520	397	220	224	204	11.9	14.8	14.7	3.14	0.20	0.30	0.45	0.92	1.39
10	4,784	560D	1.61	0.40	272	320	285	302	237	197	273	13.7	14.3	14.9	1.32	0.66	0.12	5.07	4.82	5.93
11	4,077	575D	1.82	0.57	293	442	338	488	260	206	256	13.3	14.6	14.8	1.73	0.42	0.23	0.77	1.90	3.26
12	4,086	550D	1.85	1.21	382	490	431	574	306	265	303	12.6	13.5	14.4	2.35	1.47	0.64	1.73	0.88	1.49
13	4,120	560D	1.71	0.58	251	461	459	416	201	260	192	12.9	14.1	14.8	2.06	0.92	0.22	0.39	1.02	1.42
14	4,361	600D	1.86	0.47	191	302	220	243	117	180	117	14.3	14.3	14.8	0.68	0.70	0.20	0.97	1.50	2.03
15	4,408	525D	1.86	0.32	377	391	589	397	196	246	171	14.4	13.6	14.8	0.65	1.39	0.22	1.74	1.82	1.65
16	4,160	750N	2.67*	1.56	575	411	189	167	292	165	139	13.7	14.4	14.6	1.26	0.59	0.44	15.00	6.85	5.33
Avg.	4,305																			

* VW's flow measured at 1 inch H_2O ΔP. All others measured at 18" Hg.

NOTE: Dash marks indicate that data were inadvertently not measured.

Scott Research Labs., Inc.
Project #2807

April 30, 1970

APPENDIX 6.2 TEST DATA AT 4,000 TEST MILE

Car No.	Actual Test Miles	Idle RPM	PCV Flow CFM	7-Mode Wtd Ems CO, %	7-Mode Wtd Ems HC ppm	Corrected Steady State Emissions: HC, ppm (FID) Idle	HC, ppm (FID) 20	HC, ppm (FID) 40	HC, ppm (NDIR) Idle	HC, ppm (NDIR) 20	HC, ppm (NDIR) 40	CO_2, % Idle	CO_2, % 20	CO_2, % 40	CO, % Idle	CO, % 20	CO, % 40	Oxygen Idle	Oxygen 20	Oxygen 40
17	4,492	630D	1.85	0.94	219	362	321	383	202	193	207	13.2	14.4	14.2	1.76	0.64	0.85	1.14	1.50	1.06
18	3,936	600D	1.81	2.78	496	1740	1134	592	501	432	321	7.0	9.2	14.1	7.96	5.76	0.92	0.41	0.52	1.22
19	4,982	600D	1.76	1.29	252	600	551	536	217	204	214	12.1	13.3	14.3	2.90	1.73	0.71	0.83	0.82	2.62
20	3,847	550D	1.86	0.74	320	418	429	395	224	259	197	13.4	14.8	14.8	1.63	0.23	0.23	0.51	1.13	1.58
21	4,113	520D	1.80	0.50	249	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22	4,260	530D	1.81	0.48	326	254	224	246	211	224	185	14.7	14.1	14.8	0.32	0.92	0.22	1.37	1.02	2.57
23	4,204	550D	1.75	0.64	189	401	262	351	172	157	160	12.5	14.8	14.8	2.48	0.21	0.21	0.29	0.73	1.28
24	4,263	550D	1.81	0.61	196	423	465	518	156	185	185	14.0	14.6	14.3	1.01	0.42	0.74	2.01	2.64	2.64
25	4,173	600D	1.76	0.44	222	385	296	449	193	153	214	14.2	14.6	14.7	0.83	0.42	0.33	1.04	1.27	1.64
26	4,022	550D	1.80	0.53	296	520	362	589	240	197	278	14.2	14.6	14.7	0.82	0.43	0.33	0.61	1.49	2.33
27	4,141	580D	1.80	0.48	331	510	398	578	306	287	300	14.1	14.8	14.6	0.92	0.23	0.44	0.82	3.52	2.22
28	3,864	575D	1.81	0.46	310	494	398	578	252	196	263	13.4	14.8	14.8	1.55	0.22	0.22	0.29	2.01	2.08
29	5,066	550D	1.82	0.50	231	320	473	473	105	226	170	14.4	14.3	14.6	0.60	0.72	0.41	1.00	1.54	1.34
30	4,502	520D	1.85	0.47	260	300	221	352	171	149	186	14.1	14.9	14.3	0.93	0.11	0.72	1.66	2.65	1.86
31	4,285	600D	1.83	0.64	246	407	448	353	182	240	188	14.1	13.8	14.6	0.86	1.25	0.44	1.61	1.56	1.21
32	4,113	880N	2.30*	1.06	171	486	291	261	222	157	119	13.9	14.8	14.9	1.11	0.23	0.11	8.75	3.72	2.27
Avg.	4,266																			

* VW's flow measured at 1 inch H_2O ΔP. All others measured at 18" Hg.

NOTE: Dash marks indicate that data were inadvertently not measured.

Scott Research Labs., Inc.
Project #2807

April 30, 1970

APPENDIX 6.2 TEST DATA AT 4,000 TEST MILE

Car No.	Actual Test Miles	Idle RPM	PCV Flow CFM	7-Mode Wtd Ems CO, %	7-Mode Wtd Ems HC ppm	Corrected Steady State Emissions: HC, ppm (FID) Idle	HC, ppm (FID) 20	HC, ppm (FID) 40	HC, ppm (NDIR) Idle	HC, ppm (NDIR) 20	HC, ppm (NDIR) 40	CO_2, % Idle	CO_2, % 20	CO_2, % 40	CO, % Idle	CO, % 20	CO, % 40	Oxygen Idle	Oxygen 20	Oxygen 40
33	4,257	580D	1.80	1.38	216	572	442	434	222	168	182	12.1	13.1	14.5	2.86	1.92	0.47	1.28	1.25	3.28
34	5,360	600D	1.75	1.07	245	571	393	432	230	156	176	11.6	14.0	14.4	3.40	1.01	0.57	0.92	1.31	3.64
35	3,813	600D	1.79	0.95	264	483	383	364	211	206	199	13.2	13.9	14.8	1.81	1.11	0.23	1.01	1.01	4.32
36	4,293	525D	1.76	0.55	282	470	361	263	255	175	126	13.0	14.8	14.9	2.00	0.22	0.11	1.20	2.63	2.98
37	4,240	550D	1.76	0.77	222	356	276	213	188	153	112	13.5	14.9	14.8	1.50	0.10	0.21	0.75	1.63	2.55
38	4,185	600D	1.85	0.52	232	387	362	318	189	176	148	13.1	14.7	14.8	1.94	0.32	0.22	0.48	1.49	2.08
39	4,155	580D	1.84	0.71	229	409	429	452	189	198	188	14.2	14.5	14.6	0.84	0.54	0.44	0.84	1.07	1.21
40	3,973	500D	1.88	1.04	236	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
41	4,096	590D	1.78	0.49	228	427	404	469	179	197	172	14.3	14.9	14.6	0.70	0.11	0.42	1.89	3.40	2.40
42	4,065	550D	1.75	0.92	333	-	-	-	293	257	303	11.7	14.3	14.5	3.26	0.73	0.53	0.47	1.15	1.49
43	4,712	540D	1.80	0.76	305	465	323	565	271	193	261	13.9	14.8	14.8	1.14	0.21	0.22	0.85	2.50	3.04
44	4,707	550D	1.86	0.75	306	568	416	580	239	159	227	12.1	14.8	14.8	2.87	0.22	0.23	0.76	2.19	3.07
45	3,593	540D	1.78	0.58	318	324	430	339	243	325	241	13.4	14.2	14.8	1.62	0.84	0.22	3.55	4.09	4.38
46	4,271	560D	1.82	0.59	272	360	378	346	185	248	184	13.2	14.6	14.8	1.85	0.43	0.21	1.75	2.48	1.57
47	4,792	525D	1.80	0.54	745	493	770	496	257	370	217	13.5	13.0	14.6	1.51	2.00	0.42	1.51	1.30	1.27
48	3,893	1050N	2.61*	1.73	452	154	124	216	154	211	186	13.8	13.8	14.2	1.15	1.24	0.84	10.90	8.80	7.80
Avg.	4,275																			

* VW's flow measured at 1 inch H_2O ΔP. All others measured at 18" Hg.

NOTE: Dash marks indicate that data were inadvertently not measured.

APPENDIX 6.3 NEW MULTIPLE RANGE TEST

The initial test that is conducted during the course of performing an analysis of variance is the F test of a given main or interaction effect. The F test alone, however, indicates only the rejection of the homogeneity hypothesis and does not indicate the homogeneous subsets that exist within the data set. A test that is commonly used to partition the data into subsets is one which is called the new multiple range test. The test requires: (1) the estimates of the means for each set; (2) the estimate of the standard error of the mean (S_m); and (3) the tabular value ($R_{.95}$) of the significant studentized range corresponding to the degrees of freedom (γ) and sample size (P).

The data developed in the analysis of variance of the 7-mode average hydrocarbon concentration is given as an example.

Varieties:	$\bar{M}_3$	$\bar{M}_1$	$\bar{M}_2$	$\bar{M}_5$	$\bar{M}_4$
Estimate of Means:	230.85	250.69	257.64	294.47	317.68

$$S_m = \sqrt{\frac{4591.09}{18}} = 15.97$$

$\gamma = 60$

P	$R_{.95}$	RS_m
2	2.83	45.20
3	2.98	47.59
4	3.08	49.19
5	3.14	50.15

Results: $\bar{M}_3$ $\bar{M}_1$ $\bar{M}_2$ $\bar{M}_5$ $\bar{M}_4$

APPENDIX 6.3 NEW MULTIPLE RANGE TEST - continued

As an initial step, the estimates of means are arranged in ascending order. The estimate of the standard error of the mean is computed from the given value of the mean square of the replicates (4591.09) and the sample size (18) associated with the estimate of the mean. Using the degrees of freedom of the mean square of the replicates and the sample sizes (P = 2, 3, 4, 5) of the interest, the table of significant studentized ranges for the 95 percent confidence level is entered and the tabular values ($R_{.95}$) are obtained. The product of the estimate of standard error of the mean and the $R_{.95}$ give the shortest significant range.

The differences are developed in the following order; the largest minus the smallest ($\bar{M}_4-\bar{M}_3$), the largest minus the second smallest ($\bar{M}_4-\bar{M}_1$), etc., up to the largest minus the second largest ($\bar{M}_4-\bar{M}_5$); then the second largest minus the smallest ($\bar{M}_5-\bar{M}_2$), the second largest minus the second smallest ($\bar{M}_5-\bar{M}_1$), etc., up to the second largest minus the third largest ($\bar{M}_5-\bar{M}_2$) and so on until the second smallest minus the smallest is taken ($\bar{M}_1-\bar{M}_3$).

With one exception, the estimates of means are different if the difference is greater than the shortest significant range. The exception exists if two means are a part of a subset.

The details of the computational test procedure are as follows:

1. $\bar{M}_4-\bar{M}_3 = 86.83 > 50.15$; thus $\bar{M}_4-\bar{M}_3$ is significant.
2. $\bar{M}_4-\bar{M}_1 = 66.99 > 49.19$; thus $\bar{M}_4-\bar{M}_1$ is significant.
3. $\bar{M}_4-\bar{M}_2 = 60.04 > 47.59$; thus $\bar{M}_4-\bar{M}_2$ is significant.

APPENDIX 6.3 NEW MULTIPLE RANGE TEST - continued

4. $\bar{M}_4-\bar{M}_5 = 23.21 < 45.20$; thus $\bar{M}_4-\bar{M}_5$ is not significant.

5. $\bar{M}_5-\bar{M}_3 = 63.62 > 49.19$; thus $\bar{M}_5-\bar{M}_3$ is significant.

6. $\bar{M}_5-\bar{M}_1 = 43.78 < 47.59$; thus $\bar{M}_5-\bar{M}_1$ is not significant, and hence $\bar{M}_2-\bar{M}_1$ is also not significant.

7. $\bar{M}_2-\bar{M}_3 = 26.79 < 47.59$; thus $\bar{M}_2-\bar{M}_3$ are not significant and $\bar{M}_2-\bar{M}_1$ and $\bar{M}_1-\bar{M}_3$ are not significant.

Therefore, although $\bar{M}_3$, $\bar{M}_1$, and $\bar{M}_2$ is different from set $\bar{M}_5$ and $\bar{M}_4$, $\bar{M}_1$ and $\bar{M}_5$, and $\bar{M}_2$ and $\bar{M}_5$ cannot be considered different.

APPENDIX 6.4 ANALYSIS OF VARIANCE - 7-Mode CO

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio
Make	4	2.54342	.63585	7.79
Fuel	2	.00580	.00290	0.04
Interval	1	.52136	.52136	6.39
Make x Fuel	8	.22870	.02859	0.35
Make x Interval	4	2.05086	.51271	6.28
Fuel x Interval	2	.12951	.06475	0.79
Make x Fuel x Interval	8	.78466	.09808	1.20

APPENDIX 6.4 ANALYSIS OF VARIANCE - 7-Mode HC

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio
Make	4	88757.61293	22189.40323	4.83
Fuel	2	13553.61647	6776.80823	1.48
Interval	1	9208.39255	9208.39255	2.01
Make x Fuel	8	71363.16119	8920.39515	1.94
Make x Interval	4	23776.30430	5944.07608	1.29
Fuel x Interval	2	3313.98683	1656.99341	0.36
Make x Fuel x Interval	8	28337.76885	3542.22111	0.77

APPENDIX 6.4 ANALYSIS OF VARIANCE - Idle RPM

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio
Make	4	38196.09630	9549.02407	13.12
Fuel	2	19.07148	9.53574	0.01
Interval	1	1137.77778	1137.77778	1.56
Make x Fuel	8	3128.11001	391.01375	0.54
Make x Interval	4	19543.98519	4885.99630	6.71
Fuel x Interval	2	2101.34482	1050.67241	1.44
Make x Fuel x Interval	8	5386.74778	673.34347	0.92

APPENDIX 6.4 ANALYSIS OF VARIANCE - PCV Flow (cu. ft./min.)

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio
Make	4	1.11386	.27846	76.29
Fuel	2	.00451	.00225	0.62
Interval	1	.29469	.29469	80.74
Make x Fuel	8	.05535	.00692	1.90
Make x Interval	4	1.15972	.28993	79.43
Fuel x Interval	2	.00020	.00010	0.03
Make x Fuel x Interval	8	.03443	.00430	1.18

APPENDIX 6.4 ANALYSIS OF VARIANCE - Steady State HC (FID), 20 MPH

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio
Make	4	96906.90552	24226.72638	1.83
Fuel	2	26447.39174	13223.69587	1.00
Interval	1	60611.41511	60611.41511	4.59
Make x Fuel	8	121576.76851	15197.09606	1.15
Make x Interval	4	116974.00394	29243.50099	2.21
Fuel x Interval	2	8958.63134	4479.31567	0.34
Make x Fuel x Interval	8	121390.16658	15173.77082	1.15

APPENDIX 6.4 ANALYSIS OF VARIANCE - Steady State HC (FID), 40 MPH

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio
Make	4	553915.86661	138478.96665	30.96
Fuel	2	33415.38585	16707.69292	3.74
Interval	1	80430.40489	80430.40489	17.98
Make x Fuel	8	62832.19725	7854.02466	1.76
Make x Interval	4	21302.19013	5325.54753	1.19
Fuel x Interval	2	6696.08549	3348.04274	0.75
Make x Fuel x Interval	8	43349.52595	5418.69074	1.21

APPENDIX 6.4 ANALYSIS OF VARIANCE - Steady State HC (FID), Idle

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio
Make	4	323991.59442	80997.89861	3.72
Fuel	2	27479.26518	13739.63259	0.63
Interval	1	1608.41579	1608.41579	0.07
Make x Fuel	8	111698.06062	13962.25758	0.64
Make x Interval	4	275811.79808	68952.94952	3.16
Fuel x Interval	2	6196.39882	3098.19941	0.14
Make x Fuel x Interval	8	154184.16343	19273.02043	0.88

APPENDIX 6.4 ANALYSIS OF VARIANCE - Steady State HC (NDIR), 20 MPH

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio
Make	4	48081.59590	12020.39897	5.68
Fuel	2	10729.65617	5364.82808	2.53
Interval	1	1624.09536	1624.09536	0.77
Make x Fuel	8	52686.16034	6585.77004	3.11
Make x Interval	4	17962.16178	4490.54045	2.12
Fuel x Interval	2	5387.30582	2693.65291	1.27
Make x Fuel x Interval	8	25672.69167	3209.08646	1.52

APPENDIX 6.4 ANALYSIS OF VARIANCE - Steady State HC (NDIR), 40 MPH

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio
Make	4	164910.76538	41227.69135	56.58
Fuel	2	6614.58650	3307.29325	4.54
Interval	1	7050.79511	7050.79511	9.68
Make x Fuel	8	21761.36464	2720.17058	3.73
Make x Interval	4	10890.11460	2722.52865	3.74
Fuel x Interval	2	930.07416	465.03708	0.64
Make x Fuel x Interval	8	7486.35473	935.79434	1.28

APPENDIX 6.4 ANALYSIS OF VARIANCE - Steady State HC (NDIR), Idle

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio
Make	4	83154.10781	20788.52695	10.90
Fuel	2	1150.98326	575.49163	0.30
Interval	1	2966.31729	2966.31729	1.56
Make x Fuel	8	17886.68087	2235.83511	1.17
Make x Interval	4	23489.98784	5872.49696	3.08
Fuel x Interval	2	1192.31933	596.15966	0.31
Make x Fuel x Interval	8	7834.75843	979.34480	0.51

APPENDIX 6.4 ANALYSIS OF VARIANCE - Steady State CO_2, 20 MPH

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio
Make	4	20.07290	5.01822	12.38
Fuel	2	.40703	.20351	0.50
Interval	1	1.69744	1.69744	4.19
Make x Fuel	8	1.82557	.22820	0.56
Make x Interval	4	8.01855	2.00464	4.94
Fuel x Interval	2	.87629	.43814	1.08
Make x Fuel x Interval	8	2.57629	.32204	0.79

APPENDIX 6.4 ANALYSIS OF VARIANCE - Steady State CO_2, 40 MPH

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio
Make	4	.94334	.23584	6.19
Fuel	2	.18816	.09408	2.47
Interval	1	.00081	.00081	0.02
Make x Fuel	8	.22195	.02774	0.73
Make x Interval	4	.09652	.02413	0.63
Fuel x Interval	2	.10322	.05161	1.35
Make x Fuel x Interval	8	.41687	.05211	1.37

APPENDIX 6.4 ANALYSIS OF VARIANCE - Steady State CO_2, Idle

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio
Make	4	18.36271	4.59068	7.00
Fuel	2	.98022	.49011	0.75
Interval	1	14.06596	14.06596	21.46
Make x Fuel	8	4.79626	.59953	0.91
Make x Interval	4	24.14442	6.03610	9.21
Fuel x Interval	2	1.68714	.84357	1.29
Make x Fuel x Interval	8	6.78305	.84788	1.29

APPENDIX 6.4 ANALYSIS OF VARI'NCE - Steady State CO, 20 MPH

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio
Make	4	20.07290	5.01822	12.38
Fuel	2	.40703	.20351	0.50
Interval	1	1.69744	1.69744	4.19
Make x Fuel	8	1.82557	.22820	0.56
Make x Interval	4	8.01855	2.00464	4.94
Fuel x Interval	2	.87629	.43814	1.08
Make x Fuel x Interval	8	2.57629	.32204	0.79

APPENDIX 6.4 ANALYSIS OF VARIANCE - Steady State CO, 40 MPH

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio
Make	4	.94150	.23538	6.20
Fuel	2	.18928	.09464	2.49
Interval	1	.00075	.00075	0.02
Make x Fuel	8	.22113	.02764	0.73
Make x Interval	4	.09610	.02403	0.63
Fuel x Interval	2	.10302	.05151	1.36
Make x Fuel x Interval	8	.41766	.05221	1.37

APPENDIX 6.4 ANALYSIS OF VARIANCE - Steady State CO, Idle

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio
Make	4	18.36271	4.59068	7.00
Fuel	2	.98022	.49011	0.75
Interval	1	14.06396	14.06396	21.46
Make x Fuel	8	4.79626	.59953	0.91
Make x Interval	4	24.14442	6.03610	9.21
Fuel x Interval	2	1.68714	.84357	1.29
Make x Fuel x Interval	8	6.78305	.84788	1.29

APPENDIX 6.4 ANALYSIS OF VARIANCE - Steady State O_2, 20 MPH

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio
Make	4	9.48438	2.37109	4.44
Fuel	2	1.16433	.58216	1.09
Interval	1	.40133	.40133	0.75
Make x Fuel	8	4.88306	.61038	1.15
Make x Interval	4	2.06258	.51565	0.97
Fuel x Interval	2	.71654	.35827	0.67
Make x Fuel x Interval	8	2.13683	.26710	0.50

APPENDIX 6.4 ANALYSIS OF VARIANCE - Steady State O_2, 40 MPH

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio
Make	4	20.35698	5.08975	8.40
Fuel	2	.68721	.34360	0.58
Interval	1	.01369	.01369	0.02
Make x Fuel	8	4.83239	.30403	0.83
Make x Interval	4	.59780	.14945	0.25
Fuel x Interval	2	4.60163	2.30081	3.87
Make x Fuel x Interval	8	4.88953	.61119	1.03

APPENDIX 6.4 ANALYSIS OF VARIANCE - Steady State O_2, 14Ka

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio
Make	4	3.17509	1.29362	3.38
Fuel	2	1.14283	.57141	1.57
Interval	1	.01202	.01202	0.03
Make x Fuel	8	8.72347	1.21543	2.91
Make x Interval	4	.34264	.13561	0.32
Fuel x Interval	2	.41538	.20269	0.48
Make x Fuel x Interval	8	2.31484	.28933	0.69

APPENDIX 6.5 MEAN VALUES OF SIGNIFICANT INTERACTIONS

Fuel x Interval - Steady State O_2 @ 40 MPH

(F1 x I1) = 2.17	(F2 x I1) = 2.43	(F3 x I1) = 2.18
(F2 x I2) = 2.31	(F2 x I2) = 1.85	(F3 x I2) = 2.38

Fuel x Make - Steady State O_2, Idle

(F1 x M1) = 1.286	(F2 x M1) = 1.022	(F3 x M1) = 1.00
(F1 x M2) = 1.072	(F2 x M2) = 0.973	(F3 x M2) = 0.955
(F1 x M3) = 0.786	(F2 x M3) = 1.059	(F3 x M3) = 1.020
(F1 x M4) = 2.173	(F2 x M4) = 0.650	(F3 x M4) = 0.788
(F1 x M5) = 1.283	(F2 x M5) = 1.538	(F3 x M5) = 2.042

Fuel x Make - Steady State HC (NDIR), 20 MPH

(F1 x M1) = 191.8	(F2 x M1) = 236.8	(F3 x M1) = 167.1
(F1 x M2) = 188.3	(F2 x M2) = 244.8	(F3 x M2) = 180.4
(F1 x M3) = 201.3	(F2 x M3) = 180.4	(F3 x M3) = 211.8
(F1 x M4) = 209.2	(F2 x M4) = 242.8	(F3 x M4) = 270.9
(F1 x M5) = 235.2	(F2 x M5) = 245.2	(F3 x M5) = 299.8

Fuel x Make - Steady State HC (NDIR), 40 MPH

(F1 x M1) = 185.8	(F2 x M1) = 216.2	(F3 x M1) = 163.6
(F1 x M2) = 142.9	(F2 x M2) = 148.8	(F3 x M2) = 135.8
(F1 x M3) = 188.2	(F2 x M3) = 183.5	(F3 x M3) = 189.8
(F1 x M4) = 259.5	(F2 x M4) = 270.2	(F3 x M4) = 248.8
(F1 x M5) = 192.7	(F2 x M5) = 189.2	(F3 x M5) = 211.4

APPENDIX 6.5 MEAN VALUES OF SIGNIFICANT INTERACTIONS

Interval x Make - 7-Mode CO

(I1 x M1) = 0.687	(I2 x M1) = 1.420
(I1 x M2) = 0.638	(I2 x M2) = 0.679
(I1 x M3) = 0.617	(I2 x M3) = 0.691
(I1 x M4) = 0.581	(I2 x M4) = 0.675
(I1 x M5) = 0.671	(I2 x M5) = 0.321

Interval x Make - Idle RPM

(I1 x M1) = 598	(I2 x M1) = 603
(I1 x M2) = 550	(I2 x M2) = 544
(I1 x M3) = 551	(I2 x M3) = 567
(I1 x M4) = 546	(I2 x M4) = 558
(I1 x M5) = 617	(I2 x M5) = 553

Interval x Make - PCV Flow

(I1 x M1) = 1.650	(I2 x M1) = 1.800
(I1 x M2) = 1.260	(I2 x M2) = 1.797
(I1 x M3) = 1.833	(I2 x M3) = 1.787
(I1 x M4) = 1.870	(I2 x M4) = 1.787
(I1 x M5) = 1.777	(I2 x M5) = 1.813

Interval x Make - HC (FID), Idle

(I1 x M1) = 455.3	(I2 x M1) = 666.7
(I1 x M2) = 473.7	(I2 x M2) = 385
(I1 x M3) = 439.0	(I2 x M3) = 410.0
(I1 x M4) = 543.7	(I2 x M4) = 480
(I1 x M5) = 424.7	(I2 x M5) = 372

APPENDIX 6.5 MEAN VALUES OF SIGNIFICANT INTERACTIONS

Interval x Make - HC (NDIR), 40 MPH

(I1 x M1) = 164	(I2 x M1) = 200
(I1 x M2) = 108	(I2 x M2) = 157
(I1 x M3) = 199	(I2 x M3) = 188
(I1 x M4) = 258	(I2 x M4) = 273
(I1 x M5) = 184	(I2 x M5) = 184

Interval x Make - HC (NDIR), Idle

(I1 x M1) = 190.2	(I2 x M1) = 262
I1 x M2) = 203.1	(I2 x M2) = 216.1
(I1 x M3) = 207.4	(I2 x M3) = 185.1
(I1 x M4) = 274.5	(I2 x M4) = 267.0
(I1 x M5) = 181.8	(I2 x M5) = 184.0

Interval x Make - CO_2, 20 MPH

(I1 x M1) = 14.173	(I2 x M1) = 12.736
(I1 x M2) = 14.593	(I2 x M2) = 14.647
(I1 x M3) = 14.643	(I2 x M3) = 14.647
(I1 x M4) = 14.683	(I2 x M4) = 14.487
(I1 x M5) = 13.833	(I2 x M5) = 14.067

Interval x Make - CO_2, Idle

(I1 x M1) = 13.940	(I2 x M1) = 11.167
(I1 x M2) = 13.960	(I2 x M2) = 13.373
(I1 x M3) = 13.877	(I2 x M3) = 13.670
(I1 x M4) = 13.817	(I2 x M4) = 13.223
(I1 x M5) = 13.390	(I2 x M5) = 13.803

APPENDIX 6.5 MEAN VALUES OF SIGNIFICANT INTERACTIONS

Interval x Make - CO, 20 MPH

(I1 x M1) = 0.823	(I2 x M1) = 2.257
(I1 x M2) = 0.403	(I2 x M2) = 0.347
(I1 x M3) = 0.347	(I2 x M3) = 0.380
(I1 x M4) = 0.310	(I2 x M4) = 0.507
(I1 x M5) = 1.160	(I2 x M5) = 0.927

Interval x Make - CO, Idle

(I1 x M1) = 1.053	(I2 x M1) = 3.830
(I1 x M2) = 1.030	(I2 x M2) = 1.620
(I1 x M3) = 1.117	(I2 x M3) = 1.330
(I1 x M4) = 1.183	(I2 x M4) = 1.770
(I1 x M5) = 1.400	(I2 x M5) = 1.193